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FORCES AND ATOMS

THE WORLD OF THE PHYSICIST

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ONE of the signs whereby a physicist may be known is a fondness for putting dots upon blackboards. This is not an irrational habit, but a symbolic practice. It is a symbol of his manner of regarding the world as a multitude incredibly enormous of particles incredibly small. The dots stand for the particles, and the bare regions of the blackboard for the empty spaces between them. The habit has not indeed been universal. Many a thinker has preferred to consider the world as a continuum, a solid or jelly or fluid; and we shall see that this alternative has always been very near in the background, even when the "atomists" were at their most triumphant. Let me, however, defer this other idea, and derive as much as possible from the notion of particles in a void.

But when the dots are set down on the otherwise clean board with regions of black emptiness between, the story is far from completed. It is, in fact, only begun, for the major part is yet to be written: the account of the forces among the particles. Though these last be separated from each other by spaces apparently empty, yet they are not unconscious of each other, for each of them is subject to a force—the resultant of many forces, due to all the rest.

One might attach an arrow to each dot, to signify the strength and the direction of the force which acts upon it. One might draw wandering curves all over the board, to intimate at every point the direction and strength of the force which a particle would feel, were it to be at that point. This is accepted practice, but it would be worth the doing only if our assumptions and our ambitions were much more specific than for the present they are. Perhaps at least the blackboard should be smeared with a uniform coating of chalk, to signify that a particle in space is not left entirely to itself, but feels the influence of the others. Among our not-so-distant ancestors there seems to have been a psychological need for a gesture of the sort; they talked about space as though it were filled with a "medium" or "aether," because it seemed wrong to them to say that space is empty if the particles which wander in it are subject to forces. Our generation has nearly lost the need, whether of an aether to occupy actual space or of a smear of chalk to symbolize it on the blackboard. Let us say that space is empty and leave the blackboard black between the dots, without deeming ourselves deprived of the right of saying that the particles exert and suffer forces on and from one another.

What is there to be said about the forces? A very great deal! for most of theoretical physics is made up of beliefs or ideas about the forces, augmented by the mathematical operations—very hard

and very long-winded, in far too many cases—required for making the ideas really useful. So great a program is indicated by that sentence, that I am wasting words in adding that it will not be fulfilled in one or two lectures, nor in the whole of the course. Only the most general of statements can be made in what follows. Of these I lay down at once the first, which is negative and self-evident:

The forces can not be purely repulsive. For if they were, all the particles would rush off into the uttermost depths of space, and we should have no model at all for a universe which, with all its faults, does manage at least to stick together.

Therefore there must be attractive forces, and these by and large must overpower the repulsive ones, if any such there be.

But need there be any repulsive forces at all? (Let the sophisticated reader now forget for a little that there are electrical forces which are repulsive, so that he may inquire with an open mind as to whether such could be avoided.) At first, it may not seem so; and one may invoke the great authority of Newton, who is often thought to have contented himself with assigning to all bodies the power of attracting one another with the force of gravity. He did not so content himself, and we shall learn this shortly. For the moment, let it be remembered that forces of attraction unopposed would tend to draw all the particles of the universe into a single compact clump. If the volume of each particle were infinitely small, so also would be that of the ultimate clump; if the volume of each particle were irreducible below a certain minimum—but we shall ere long find what *that* idea can involve us in! Briefly, there must be something to oppose the attractive forces. To call this something by the name of "force," or even to call it by any single name, would be to limit it unduly. So to the second general statement I give the form:

There must be attractive forces, but there must also be antagonists to them.

If some one wanted a particular problem of the theory of physics identified to him as the profoundest, the problem of these antagonists might well be selected as such.

There is indeed one famed and spectacular case, which makes one antagonist clear. It is the case of the heavenly bodies: the planets revolving around the sun, the satellites around the planets. Why does not the moon fall onto the earth and the earth fall into the sun? Newton's laws of motion tell the answer. The antagonist is *motion*—or, to speak more precisely, momentum—or, to speak yet more precisely, angular momentum. If two particles attract one another but are moving with a relative motion which is not along the line that joins them, they never will meet. However great the attraction between them, it can not draw them together. Attraction can do no more than constrain them to swing in permanent orbits around their common center of mass. Therefore,

The celestial bodies exhibit to us a system kept stable by the attraction of gravity, with motion for the antagonist thereto.

However natural this statement may now seem, it is by no means an idea inborn in the human mind. There was an era when it was believed that motion dies out of itself, unless continually sustained by a never-ceasing stimulus. Were motion to die out of itself, it could not be an eternal antagonist to gravity. Newton cleared the way for the new idea by abolishing the old one.

May we now assume that the ultimate particles of the world act on each other by gravity alone, with motion as the sole antagonist to keep the universe from gathering into a single clump?

The answer to this question is a forthright and irrevocable *no*.

That the answer should be *no* is not at all surprising to this generation, which is familiar with other forces than gravity,

the electromagnetic forces especially. Those who underrate the prowess of our forerunners may feel surprise on hearing that the negative answer was quite as apparent to Newton. No apology is ever needed for quoting verbatim what Newton wrote in English, though it is a dangerous act for the quoter, whose writing must suffer by contrast with the simple elegance of the seventeenth century. Incurring the danger, I cite from the "Opticks" (a book of which the name falls decidedly short of the scope):

> The attractions of gravity, magnetism and electricity reach to very sensible distances, and so have been observed by vulgar eyes, and there may be others which reach to so small distances as hitherto escape observation. . . . The parts of all homogeneal hard bodies which fully touch one another stick together very strongly. And for explaining how this may be, some have invented hooked atoms, which is begging the question; and others tell us that bodies are glued together by rest, that is, by an occult quality, or rather by nothing; and others, that they stick together by conspiring motions, that is, by relative rest among themselves.[2] I had rather infer from their cohesion, that their particles attract one another by some force, which in immediate contact is exceedingly strong, at small distances performs chemical operations, and reaches not far from the particles with any sensible effect.

Further along in the "Opticks" we read:

> Thus Nature will be very conformable to herself and very simple, performing all the great motions of the heavenly bodies by the attraction of gravity which intercedes those bodies, and almost all the small ones of their particles by some other attractive and repelling powers which intercede the particles.

With the powerful aid of Newton we have now distinguished between the attractive force of gravity and another attractive force, for which I retain the old-fashioned name "cohesion." I give another basis of distinction, one which could not have been found until in the mid-nineteenth century the equivalence of heat with mechanical work was established. Consider a piece of solid or liquid matter, and put the question: how much work must be done to tear its atoms apart and dissipate them into the infinite reaches of space, if the only force whereby they act on one another is the attraction of gravity? The question is answerable, if it is known how massive the atoms are and how far apart (on the average) they are. These things are known. The result of the computation is to be compared with the amount of work which is actually expended—in the form of heat—when the solid or liquid is volatilized into vapor. It is found that only about the billionth part of a millionth part of the heat so spent is devoted to "breaking down the gravitational bond," to doing work against the attraction of gravity which is overcome when the atoms are dispersed.[3] All the rest is required for overcoming that more intimate force of cohesion.

Gravity now is pushed into the background, and sinks into the relative insignificance which may be gauged from the fact that in the endless speculations of physicists and chemists as to how matter is built up and joined together, it is completely left out. The force which dominates the planets, which makes a hill so hard to climb and a height so dangerous to fall from—how amazing that it should be trivial, compared with others which the flame of the gas-jet vanquishes as the water boils out of the kettle! Trivial of course by comparison only, and at small distances, not at great; or to phrase the situation better, it is the force of cohesion

[2] These remarks seem to be aimed at Lucretius, or else at the Greeks from whom Lucretius took some of his ideas.

[3] The computation for mercury was made by my colleague, Dr. L. A. MacColl, on the basis most favorable to gravity: by assuming mercury to be a continuum, or in other words, to be made up of infinitesimal atoms infinitely close together—an assumption giving the greatest possible value to the work required for spreading the mercury through infinite space, if gravity be the only restraint. The latent heat of vaporization of mercury is found by experiment to be $1.88.10^{16}$ times this value. Thus the contrast mentioned in the text is not contingent upon knowledge of the mass and spacing of the atoms, though the knowledge is available if wanted.

which is trivial at great distances, gigantic at small. This is the contrast which is implied by the technical terms of physics, "long-range forces" versus "short-range forces." Gravity is long-range, because it falls away gently with increase of distance; cohesion is short-range, because it falls away precipitately. We shall soon be meeting with other examples of either character.

One other fact to illustrate the short-range quality of the cohesive forces: When a kettle of water is boiling away on the stove, the amount of heat consumed in dispersing the first cubic inch that departs is the same as is spent in dispersing the second, and the third, and each of the others down to and including the last. This could not be so, if the particles were drawn together by important long-range forces; for then each cubic inch would be easier to drive off than that which last preceded it into the vaporous state, since there would be less of the liquid remaining behind to attract it.

The celestial bodies—useful as they have been in showing us the laws of motion—have therefore served us badly by hinting that gravity is the sole attractive force, a hint which is quite misleading. In another important respect they fail to give us a lead: they show us no examples of collision. Collision, more commonly known as impact, is one of the most important of earthly phenomena, as it is one of the most uncomfortable. The apple which fell in the orchard of Newton, and inspired him with the law of gravitation, may have been a legendary apple; if it was real, we may be sure that it ended its fall in a collision—ended its fall, not its existence. It did not pass through the globe and pop out of the ground in the Antipodes; it did not instantly merge with the grass or the soil of the orchard; it bounced and rolled a little, perhaps, and then lay quietly pressing against the earth, entire and whole. The earth was impenetrable to the apple, as the apple to the earth.

We do not even have to look to impact, to be taught this lesson about the impenetrable. Not less impressive than the fact that the piece of iron sticks together, is the fact that it does not shrink. For any particular choice of temperature and pressure, it has a particular volume which is its own. Work or heat must be expended to dilate it or tear it apart altogether, but also work must be expended to make it denser.

Having ascribed to attractive forces the fact that it takes heat—or let me say henceforward, energy—to vaporize a piece of matter solid or liquid, we now ascribe to repulsive forces the fact that it takes energy to squeeze the piece. The forces must be short-range—still more short-range than are the cohesive forces, inasmuch as these come into play to capture the atoms and hold them together, before those get their opportunity of crying "hold, enough!" They must be very potent, for the most terrific pressures which have been achieved by man do not avail to squeeze the most compressible solid into one-third of its original volume. Why talk of artificial pressures? Everywhere in the globe of the earth, except within a hundred miles of the surface, the pressure is greater by far than any of them; and yet, the average density of the earth is less than double that of its superficial crust.

We have imagined that as two atoms approach each other, the gravitational force between them rises gently, the cohesive force remaining undetectable till they come very close together, when at some critical distance it begins a sharp and sudden rise which quickly carries its value far over that of gravity. Now we are to conceive of yet a third force, repulsive, undetectable till they come still closer together, then at a lesser critical distance entering on a sharper more sudden rise which rapidly carries its value far over those of both of the other two.

This essential and powerful force has no name of its own. This is because it is

usually described in words not conveying directly the notion of force. What we have now encountered is the concept of the incompressible atom, the particle of irreducible volume—the doctrine that the atoms are to be pictured not as infinitely small like the points of geometry, but as hard impenetrable elastic pellets, minute indeed but not inconceivably so. This is a doctrine frankly expressed by many a thinker of the past, who perhaps was more unwilling than we to receive uncritically that difficult dogma of the point of infinite smallness. Hearken again to Newton: "It seems probable to me that God in the beginning formed matter in solid, hard, massy, impenetrable, moveable particles . . . incomparably harder than any porous bodies compounded of them; even so very hard, as never to wear or break in pieces; no ordinary power being able to divide what God himself made one in the first creation."

The completely unsqueezable atom corresponds to a force of repulsion which passes suddenly from zero to an infinite strength at a certain critical distance. The critical distance is the "radius of the atom." Reversely the idea of a force of repulsion rising rapidly indeed, but always continuously, as two particles draw nearer—this corresponds to a squeezable atom, without a definite radius. Solids and liquids in bulk are compressible, and this seems to rule out the former idea, which anyhow is more drastic than one likes to accept. It is not ruled entirely out, for there may be interstices among the particles, and the shrinkage entailed by pressure may be ascribed to the atoms so setting themselves that the cavities lessen in size. However, this does not seem adequate, and it is better to accept a compressible atom and make it share with the cavities the responsibility for the shrinkage. Then there is also the fact that solids expand when warmed. This is ascribed to the atoms dancing around with the heat, and so we approach a new situation in which repulsion and motion are allied as the two antagonists to cohesion.

Instead of exploring this situation further, let us ask whether there is a difference between the concept of the more-or-less squeezable atom and that of the force-field curiously devised which I have been describing. Formally, there is not. But in respect of the path which the mind next tries to follow, there is a difference, and a great one.

The compressible atom being accepted, one asks, of what is it made? and finds that one is thinking of a continuous substance, elastic and dense. One who is trying to become a thoroughgoing atomist is hardly pleased to discover a continuum at the base of the theory. The displeasure would not be long-lasting, if by assigning a few simple qualities to the continuum one could arrive at the right numerical values for things that can be measured—if one could infer, for instance, that the continuum by its nature divides itself into globules of just the same radii as the structure of crystals demands for the atoms. We are to meet in nuclear physics with a calculation singularly like this—but in general, the feat has not been done. It is not an adequate retort to say that the thoroughgoing atomist is obliged to assign to his atoms the sizes and the masses which they actually have, without giving any deeper reason. He manages to avoid the question; it becomes imperious, when the continuum is brought upon the scene. The road to success may lie by way of the continuum, but it is a road that has not been successfully trodden.

The force-field around the point-particle being accepted, one asks, why this so curious force-field? An inverse-square field would seem so natural as not even to ask for further explanation (but this is probably because the human mind has had two and a half centuries for getting accustomed to it). This combination of a short-range attraction with a repulsion still shorter in range cries out for explanation. Could one but somehow re-

duce it all to inverse-square forces, one would be more contented. This road seems impassable, but already it has been trodden—built and trodden—to splendid successes. Therefore I lay aside the compressible atom scooped out of a continuum, mentioning that even now we have not heard the last of it. Two stages of preparation are now required.

First, I must take more care henceforward in using the words "atom" and "particle." Hitherto I have used them interchangeably; from this moment on, "atom" is to have one meaning and "particle" another. Of the two, it will be "atom" which comes the closer to meaning what both words have meant up to now. Atom will attract atom by the force of cohesion; atom will repel atom by the nameless short-range force. The atoms in their turn will be made up of more elementary particles, bearing such names as "nucleus" and "electron." As to the forces between them—that is the topic to which we are coming.

Second, I must introduce at long last the forces which the reader has so long been missing from this discourse: the electromagnetic.

Of these, it is the "electrostatic" force which stationary charges exert on one another which concerns us the most. Newton spoke of it in one of the passages which I have just been citing, but the pleasure was denied him of knowing how it resembles gravity. Both follow the law of the inverse-square; yet a hundred years were to elapse between the times when Newton proved this for the one and Coulomb for the other. The electrostatic force is broader though than gravity, for it includes an attraction and a repulsion. There are two categories of charge, the positive and the negative: any charge repels those of its own category, attracts those of the other.

This entry upon the scene of a long-range repulsion modifies the prospects of a successful picture of the world as a congeries of particles, and seems at first glance to brighten them greatly. Dismiss gravity—forget about cohesion—put the question: in an imaginary universe made up of electrified particles some positive and some negative, acting on one another by electrostatic forces only, is it possible to have stability with all the particles standing still?

Again the answer is no. This is not, however, too disappointing: we are accustomed to motion as the antagonist of gravity in the celestial case; shall we not now introduce it to be an ally to the electrostatic repulsion, the two of them conjointly being the antagonists of the attraction?

Now with real surprise and disappointment, one stands confronted again by the ruthless negative answer. The past revives: I have said that a pre-Newtonian philosopher would scarcely have accepted motion as the deathless antagonist to gravity, because he would have believed that motion dies out of itself. Well, the motion of an electrified particle *does* die out of itself—so says the electromagnetic theory. A proviso must here be inserted for correctness's sake, though it does not alter the situation. Uniform motion does not tend to die out—but uniform motion is useless to our ambitions. The orbital motion of a planet, the swing of a pendulum—on these the theory must be built; but these are accelerated motions; and accelerated motions destroy themselves, when the moving body is electrified. Their energy passes into light, and the body sinks to rest. Aristotle was avenged in the nineteenth century on those who sneered at him; for what he had believed of motion generally, was in effect what they believed of the motion of electricity. Still, as nearly every one knows, there is, after all, an electrical theory of matter; the elementary particles are deemed to be electrified, and the forces between them are deemed to be electromagnetic.

How is all this to be reconciled? By a statement which is the prelude to the

final one—provided, that is, that all works out as well as physicists now hope, and provided also that we avert our eyes from the phenomena called "nuclear." Having imagined the elementary particles as points possessed of mass and bearing charges, and acting upon one another by electromagnetic forces, we are to treat their motions by the method of quantum mechanics, and not by the method of classic mechanics.

I will not pretend that this is a slight innovation, nor try to represent it as anything less than a great and difficult revolution in some of our most cherished habits of thought. Concepts formerly sharp, even those of position and motion themselves, become hazy; there are pitfalls and labyrinths; the mathematical technique is novel and hard. Yet in the picture of the universe as now presented, there are particles possessed of charge and mass; there are electromagnetic forces between the particles; there is motion of the particles; there is radiation, which it is just barely permissible to disregard in an outline like this one, and which I am disregarding; and outside of the realm of "nuclear" phenomena, there is nothing else. The stability of the world, that is to say, of the picture, is assured by attractions and repulsions electrical in nature, and by motion, with radiation playing an essential part.

The hydrogen atom appears before the eye of the mind as a system of a nucleus and an electron: two particles of known, equal and opposite charges, of known unequal masses, attracting one another by electrostatic force. The force draws them together, but there is kinetic energy and there is motion, and so they stay apart. It takes a definite amount of energy to separate them, and the theory derives its actual value very exactly from a basic principle. Any other atom appears before the mind as a system of a nucleus and two or more electrons. The nucleus bears a positive charge, the electrons are negative; the nucleus attracts the electrons, but they repel one another; there is motion; between the attraction and the motion and the repulsion, there is stability. A molecule is a system of two or more nuclei positively charged and two or more electrons negatively charged, and the same three qualities hold the balance. A tangible piece of metal is an enormous multitude of nuclei and electrons, these latter enjoying a very wide variety of motions, some moving almost as freely as though the metal were a vacuum: again the balance is held, the metal tending neither to shrink nor to explode.

All this is a programme for the explanation of nature; and it is a programme which has been largely fulfilled—wherefore this lecture and a portion of the course. Not everything has been explained, nor ever will be. Quite apart from the phenomena called nuclear, there are countless things and happenings on earth which are so complicated that they may well obey our fundamental laws without ever giving us the chance to prove it. If we should apply our assumptions to them and start to work out the consequences, it would take a geological era to finish the job. Perhaps all phenomena of life are of this type. The most that can be asked for is, that the theory should deal capably with all the phenomena for which it can not reasonably be claimed that they are so complex as to defy any theory. I do not allege that our theory of massive particles, electromagnetic forces and quantum mechanics has done even this. It has, however, done a great deal, so much that it takes a rather skeptical physicist to deny it in the realms to which it lays claim.

In the light of this theory, let us consider the situation of the several forces.

Gravity remains apart and inaccessible, one of the ultimate forces, quite probably a quality of space as Einstein has proposed.

The *electromagnetic forces* remain ultimate, not explained in terms of anything else, united among themselves by the theory of relativity, responsible for the incessant passage of energy to and fro between matter and light which is one of the major features of the world. The ionization of atoms, the generation and the absorption of light, show us these forces at work within the atoms, holding together the electrified particles of which the atoms are made, balanced by motion and by their own dual character of attractions and repulsions.

Cohesion, and the chemical forces which bind atoms into molecules and grade insensibly into cohesion, and the nameless *repulsive* force which holds the balance to them and led many to the concept of the more-or-less-compressible atom: these are derivable from the electromagnetic forces between the elementary particles whereof the atoms are made up. I repeat: *derivable from the electromagnetic forces, with the aid of quantum mechanics*—without which aid they would not have been derived. In the literature one finds incessant reference to "exchange forces"; these are not a novel category, but a step in the derivation.[4] Here are the fields of research where work is the most active. The theory of chemical forces, which some call "quantum chemistry," is well advanced; the theory of metals, not so well. Much earlier and much more often than we like, do we impinge on the class of phenomena, for which it can all too reasonably be claimed that they are so complex as to defy the theorist probably for all time. Yet there are many simple ones which have brilliantly been explained, and there is satisfaction on the whole—until one raises the eyes and looks ahead: for the nuclear phenomena are still before us.

As a prelude to these we may view the electron itself. Hardly have we begun to "look narrowly" upon it, before we see the specter rising up of that old antithesis between the point-atom and the atom carved out of a continuum; nor is it long before the specter grows more frightful than it was in the earlier case. If the point-electron is adopted, all the old conceptual troubles return in the company of a new one. The intrinsic energy of this point-particle is infinite—so says the electromagnetic theory; the mass must therefore be infinite—so says the relation of Einstein of which I will presently show the power. If from this alternative we rebound to that of a globule of continuous electrical fluid, the old difficulties come back in the company of another new one. The parts of the globule of negative electricity repel each other, so our electron-model turns out to be a high-explosive bomb. The reader, if he wishes, may seek in Lorentz' "Theory of Electrons," a classic of some thirty years ago, the details of a scheme for preventing the electron from exploding by means of non-electrical forces—a surrender, therefore, of the view-point that the ultimate forces are electrical.

Leaving these difficulties still unmastered, I turn to nuclear physics. This is a term which covers two fields: on the one hand, the structure and the qualities of atom-nuclei; on the other, some remarkable attributes of electrons, which they display either when they have tremendous energies, or under conditions which it takes tremendous energies to create. "Tremendous" energies are enjoyed by electrons fresh from radioactive substances, are obtained from the cyclotron and the electrostatic generator, and are found at their extremest in the cosmic rays. Of these attributes the only one which I will mention is mortality.

Mortality: this is a very obnoxious attribute for an elementary particle.

[4] There is also a strange quality of nature bearing in quantum-mechanics the name of "the exclusion-principle of Pauli," which to some extent resembles a repulsive force acting between similar particles such as electron and electron or proton and proton, under very special conditions.

All atomists heretofore have devised their atoms specifically to be immortal, to be *the* immortal things, to be the one thing permanently changeless under the flux of phenomena. But the electron is mortal, subject to birth and to death. Electrons are born in pairs, a positive and a negative springing together into existence. Electrons die in pairs, a positive uniting with a negative and the two of them passing out of existence.

These are not exactly cases of something coming out of nothing and something turning into nothing. Energy, mass and momentum are all conserved. Corpuscles of light disappear where and when an electron-pair is born, are born where and when a pair of electrons vanishes. So far as can be told, the corpuscles of light possess just the energy, just the mass and just the momentum which is destined to go to the nascent electrons or to be left unpossessed by those about to die. Now I have to admit my fault in not elevating earlier the corpuscles of light to a parity with the electrons and the atoms. They have the singular attribute of moving always with the same speed (when in a vacuum); they do not collide with one another, or rather such collisions have not been detected, though collisions with electrons are known; and they suffer from mortality, very much more so than do electrons. (Positive electrons are so rare that negative electrons enjoy an almost perfect security.) Immortality is reserved for energy, mass and momentum. Now we feel ourselves swerving again toward a continuum-theory. The ground is slippery, and I step hastily from it into the last section of this paper, into nuclear physics proper.

All the theory of nuclei is firmly grounded on one basic statement, which is this: the masses of all nuclei are *nearly* integer multiples of a common unit, this being *slightly less than* the mass of the lightest among them.

Here is a statement bitterly disappointing! The little word "nearly" and the three little words "slightly less than" conjointly make a bright hope stillborn. Were it not for those words, we should already have joyously leaped to the conclusion that all nuclei are clusters of a single kind of fundamental particle, different clusters differing only in how many of the particles they comprise. The conclusion is so tempting that one is quite unable to resist it, hoping against hope that the words of frustration can somehow or other be cancelled. Soothing the reader with this veiled assurance, I adopt the conclusion.

The conclusion itself must be tempered at once, for there is a second basic statement coequal with the first: the charges of all nuclei are integer multiples of a common unit of charge. No pernicious adverbs here! This statement is an exact one, to the best of our knowledge and belief. The common unit of charge, as nearly every one knows, is equal to the electron-charge and positive in sign.

The conclusion would still be sound, if the charges of all nuclei were proportionate to their masses (we should merely attribute an equal charge to every particle). Definitely this is not so, being most strikingly denied by the fact of "isobars": there are nuclear-types agreeing in mass, disagreeing in charge. We seek the next simplest assumption, and find that it suffices: Two types of fundamental particles—equal in mass—the one of them charged positively, the other neutral—each nucleus to be distinguished by two integers, one being the number of the charged component particles of the cluster, the other the number of the neutrals—"proton" and "neutron" for the names of the two.

This is the beginning of the program for nuclear theory. Having taken the first step by writing it down, we enter upon the second—and find ourselves on the very road which our ancestors trod when atomic theory was new, facing the same ascents, the same passes and the

same morasses. The long-range forces—the short-range forces—the cohesion—the repulsion—the more-or-less-incompressible particle—the troubles of the concept of the point-particle—the countervailing troubles of the continuum carven into globules—the dream of reducing everything to long-range forces and motion holding each other in balance—every one of these rejoins us on our journey. The mighty difference is, that the road still ends in the darkness, and the dream is still a dream. Therefore it is that the language of nuclear theorists wanders about in the most disconcerting way, so that often in a single article the wording in one place will be intelligible only to a few hundred (if so many) of the most advanced of specialists, and in another will sound like the voice of Newton speaking out of the "Opticks," only in a much more cumbrous manner.

In the atomic world we have already seen how gravitation is neglected, being pushed into the background by the electromagnetic forces and the cohesions and repulsions derivable from these. Now in their turn the electromagnetic forces must recede into the background. This sounds extraordinary. Have we not all been told of the supreme importance of nuclear charges? Have we not been taught that by its charge a nucleus attracts electrons and organizes them into a family about itself and so creates an atom—an atom which coheres with others, so that the world as we know it is organized by the charges of nuclei? All this is true, and very important from our view-point—but not so important, it seems, from the view-point of a nucleus. To this little cluster of protons and neutrons, the mass is more important than the charge; the total number of its component particles is more important than the number of protons separately or the number of neutrons separately; the cohesive forces are more important than the electrical. Perhaps a nucleus cares little about its charge, and nothing at all about the swarm of electrons which that charge coerces to swirl about it like a cloud of flies, though if it were not for those swirls the world would be barren and dead.

The cohesive forces certainly overpower the electrical. We are in no doubt of this, for the electrical forces are repulsive. Newton had gravity available for binding his atoms together; it was of the right type but inadequate, so he gave it cohesion as an ally. The electrostatic force between proton and proton is a repulsion, so to bind such particles together the Newtons of nuclear physics must overcome it with cohesion as an adversary. How greatly it is overcome is shown in much the same sort of way, as I followed when invoking the vaporization of solids to show how greatly the cohesion of atom with atom surpasses gravity. It is possible (at the end I will mention how) to compare the amount of energy required for tearing apart a cluster of two protons and a neutron with that required for tearing apart a cluster of two neutrons and one proton. The two amounts differ by only a few per cent.; and more surprising yet, the former is the greater! Though the first-named of the clusters contains the inherent explosive power of two protons trying to drive themselves apart by the long-range repulsion, it is stuck tighter together than the other, which contains nothing of the sort. As a minor detail this shows that the cohesive forces depend to some extent on whether the particles are neutrons or protons; but the major conclusion is, that the cohesive forces are the masters.

Are they short-range or long-range? By calling them "cohesive" I have already committed myself, but correctly. There is an argument quite similar to the second which I drew from the vaporization of liquids. Think again of the kettle of water boiling away on the stove. It takes as much energy from the flame

to disperse the last cubic inch of water that goes as it does to drive off the first, despite the fact that the first is exposed to all the long-range forces of attraction exerted on it by all the other cubic inches remaining in the kettle, and the last is not. Therefore the long-range forces which act between atom and atom are trivial, and cohesion is a force exerted by the atoms on their near neighbors only. Think now of the cluster of protons and neutrons which is a nucleus—a massive one by choice, built of two hundred particles or more. Imagine it taken to pieces by detaching one particle after another. I admit that this precise experiment is beyond the art of the physicist, but for a certain reason—the one which I have already promised to give, and will give at the end—he is as confident of its result, as he ever is of the result of any experiment which he has not actually performed. The result is, that it takes *roughly* as much energy to remove a particle when there are two hundred left behind to pull it back, as when there are but a dozen left behind, or any number in between. Therefore the long-range forces which act between the fundamental particles are minor, and the intra-nuclear cohesion is a short-range force.

I have carefully made these last statements rather weaker than their analogues for the water boiling away. The amount of energy required for taking away a particle does depend to some extent on the number left behind, and the long-range forces are therefore minor but not trivial. If the long-range forces are attractive, the binding-energy of a particle—this is the shorter name which is given to the "energy required for taking away a particle"[5]—must be greater, the greater the size of the cluster, i.e., the greater the mass of the nucleus. Now for nuclei of some fifty particles or more, the contrary is the case. Therefore the long-range force, or the major one if there are more than one, is a repulsion. We already know of one long-range repulsion, to wit, the electrostatic force between proton and proton. Is this the force in question? The answer is oddly difficult to give with assurance, but at present is believed to be *yes*.

If the answer is definitely *yes*, then the electrostatic force has after all one role of supreme importance in nuclei. It fixes their maximum size and their maximum charge, therefore limits the number of chemical elements, and may indeed be all that prevents the universe from caving together into a single lump of protons and neutrons with the electrons fluttering helplessly around it. So long have the chemists been on the search for new elements, and so completely have they searched, that we may believe them when they say that apart from the works of the "atom-smashers," no nucleus exists having more than 238 particles altogether, 92 of which are protons. Even the atom-smashers or (as I should rather call them) the transmuters, for all the wonder and power of their art, have not forced the total number of protons upward by more than two or the total number of particles altogether upward by more than one. Moreover, all the two dozen or so most massive nuclei known are subject to explosion—to explosions quite terrific, some of them spontaneous, others touched off by what seems a very minor cause. It may therefore be taken as nearly certain that there is an upper limit to the size of nuclei, and probable that it is electrostatic force that sets the limit.

Now we come down to the short-range repulsion. Such a one there must be, for again we can rehearse the ancient argument. A piece of iron does not shrink into a point; therefore the iron atoms must either exert a force of repulsion or else be more-or-less compressible pellets.

[5] It ought strictly to be called the "unbinding-energy" or "binding lack-of-energy," since it is given as positive when energy must be contributed to the system in order to detach the particle.

A nucleus does not shrink into a point, but offers an impenetrable front, measurable though small, to an oncoming neutron; therefore the nuclear particles—but why repeat the words?

Shall we interpret neutrons and protons alike as systems of particles still smaller, acting on one another by electromagnetic forces, to be treated by quantum mechanics? Alas, if there is one surety in this field, it is that we can not play quite the same game twice. Quantum mechanics may not be used up (some think that it is) but the electromagnetic forces certainly are. In this direction we have as yet no leadership.

Shall we then adopt the compressible globule or the point-particle with a curious field of force surrounding it? Though the language of nuclear theorists verges sometimes on the former, it is the latter practice which is common—a fact which will hardly surprise the reader. In the specialized literature, one finds many a speculation and (what is of more moment) many an inference about the force-field which is drawn pretty directly from reliable data. As a rule the inferences are expressed in language very different from the phrases of this lecture: "interaction" is used instead of "force-field," and there are queer and slightly comic technical terms such as "potential-well." When you read of a "rectangular potential-well," interpret that what I have been calling the "cohesive force" becomes suddenly enormous at a certain specific radius; when of an "error-well" (!) understand that the cohesive force increases rapidly according to a certain law with decline of distance; when of a "Coulomb interaction" realize that it is the inverse-square force-field of the electrostatic repulsion between proton and proton. Of these interactions I will give only two facts: first, that the short-range attraction is confined within a very few times 10^{-13} cm of the center of the proton or neutron, whereas the cohesive attraction of atom for atom spreads over a radius a hundred thousand times as great; second, that the three short-range attractions of proton for proton, neutron for neutron and neutron for proton are nearly the same.

Shall we adopt the force-fields as given to us by experiment, with some plausible assumptions added (for one can not as yet do without them) and operate on them by the procedures of quantum mechanics, hoping to arrive at (say) values of binding-energies compatible with the data? This is the present, or perhaps I should say the recent, programme of nuclear theory. If one reads the theoretical papers of any one year out of the last ten, one may readily get the impression that success is just around the corner. But if one reads the papers of two or more years and takes note of the rapid changes, the prospect does not look quite so rosy—nor when one overhears the conversations of the theorists themselves. I will not conduct the reader down the paths which are as yet so tortuous and hazy; it will be better to fill in the picture with a few of the many remaining details.

Mass was the first of properties (along with hardness) to be assigned to the elementary particles; the second was charge; to these have lately been added angular momentum and magnetic moment. It is difficult to say when the idea of a spinning atom was first propounded (one recalls the vortices in a continuous fluid which Kelvin introduced as one of the most brilliant of all attempts to contrive a continuum and atoms as a part of it) but easy to fix the time when the idea of the spinning electron became so definite and sharp, as to be successfully used in explaining crucial data; this was 1925. The electron, the proton and the neutron all have equal angular momentum; its amount, common to these three which at present claim most strongly the rank of *elementary* particle, is one of the universal con-

stants. When protons and neutrons are assembled in a nucleus, their axes of spin all point in an identical direction, though not by any means necessarily in the same sense in that direction. It is possible for a nucleus to have zero angular momentum, through half of its particles setting themselves in the one sense and half in the other; the lightest nucleus for which this happens is the alpha-particle, composed of two protons and two neutrons. The magnetic moments of the three elementary particles are very far from equal, that of the electron being some seven hundred times as great as that of the proton, which in turn is half again as great as that of the neutron. One of the tragedies of theoretical physics occurred in this connection. A principle of quantum mechanics had been proposed, superbly capable of serving as a basis for most of the incomplete principles which had already so well justified themselves in atomic physics, and including among its parts the actual values of the angular momentum and magnetic moment of the electron. Its empire would have been extended, had the ratio of the magnetic moments of proton and electron been equal to the reciprocal of the ratio of the masses of these two—actually the former ratio is too great by a factor of 2.78. This contretemps has led many to deny the title of "elementary" particle to the proton; while as for the neutron, the fact that it lacks an apparent electric charge while nevertheless displaying a magnetic moment leaves it also open to suspicion.

Few readers of these pages will be unaware that electrons are observed proceeding out of nuclei: it may well be a source of wonderment that they are denied a residence in these assemblages of protons and neutrons only. This is of course another example of the mortality of the electron. Having observed that it is subject to birth and to death, should we be deterred from supposing that it is born as it quits the nucleus from which it comes? This rhetorical question gives a false impression of the course of history. There was indeed an era when electrons were believed to inhabit nuclei, when nuclei were regarded as assemblies of protons and electrons only. It ended in 1932; but the observation of the birth and the death of electrons did not ensue for yet another year. What happened in 1932 was the discovery of the free neutron. Only when this particle had been discovered did a physicist (Heisenberg) think it worth while to begin to develop in detail the theory that the components of nuclei are protons and neutrons and no other particles but these.

Now I bring this article to a close by fulfilling my promise to speak of Einstein's relation between energy and mass, which on the one hand has been rigorously tested in the realm of nuclear physics, and on the other has extended that realm.

The relation may be worded in several ways; I will employ the shortest: *energy has mass.*

Now imagine an assemblage of particles sticking together. "Sticking together" is not the dignified phrase of a physicist; such a one would say, more abstractly but more exactly, that energy must be given the particles to take them apart. But energy has mass; therefore the mass of the assemblage must be augmented, when they are taken apart. Therefore the mass of the interconnected assembly is less than the sum of the masses of the particles when free.

Now with a single stroke this principle does away with what otherwise would have been a quite unsurmountable obstacle to the doctrine that all nuclei are made up of protons and neutrons. For "proton" and "neutron" are not merely the names of hypothetical particles whereof nuclei are made up; they are also the names of the two lightest of nuclei. These two lightest of the nuclei

are so massive, that it could not possibly be said that the other nuclei are made up of them, were it not for the detraction of mass which occurs when they are bound up together. This deficit of mass corresponds to the unbinding-energy or, badly called, the binding-energy of which I earlier spoke. The binding-energy is the amount of energy which must be supplied to the nucleus, to break it up into protons and neutrons. The deficit of mass—the difference between the actual mass of the nucleus, and the masses of all its neutrons and protons dispersed into freedom—is related to the binding-energy by Einstein's relation.

I have said that this relation has been tested in the realm of nuclear physics, and has served also to extend that realm. The possibility of testing arises from the fact that in certain cases the physicist is able to convert a system of two nuclei into a system of two other nuclei, the masses of all four being known. This seems a somewhat pedantic way of expressing the well-known fact that in performing an act of transmutation, the physicist causes one nucleus as "projectile" to impinge upon another as "target," whereupon the two merge and two others spring apart from the scene of the merger. The masses of the two initial nuclei do not as a rule add up to the same precise sum as the masses of the two final nuclei. But if to the first pair of masses we add that of the kinetic energy of the projectile, and if the second pair is augmented by that of the kinetic energies of the final nuclei—why, then, the equation balances, and Einstein's relation is justified.

As for the extensions of the realm of nuclear physics, or let me rather say, the realm of physics generally: no fewer than three have been stressed in these few pages. First, mass could not be conserved in the birth or the death of electron-pairs, were not the energy of the electrons accompanied by its mass when it passes out of or into the form of radiant energy. Then, we should have had no prior hint[7] that the system of two protons and one neutron requires more energy to unbind it, than the system of two neutrons and one proton; this was deducible from the masses of these two nuclei, before it was attested by the discovery that the latter changes spontaneously into the former. Then, we should not have the evidence that the binding-energy of the individual particle lessens, as the number of particles remaining behind in the nucleus increases; for this is a statement derived from observations on the masses of the nuclei.

So all seems well with the model of the nucleus as a system of protons and neutrons, and the particle-theory stands triumphant. Yet notice at what a price this triumph has been bought! Of all the attributes of the fundamental atom, of the elementary particle, constancy of mass was the earliest and the most firmly accepted. The elementary particle was a bit of immutable mass, set forever apart from change. Now it turns out that when the particle adheres to another, some of its mass departs. What has departed is not perished and gone. It is known sometimes to have passed into radiant energy, sometimes into energy of motion, sometimes into that mingling of the two which is known by the name of heat. Changelessness has ceased to be the quality of the atom, remaining that of the mass and the energy of the world as a whole. Immortality has gone from the atom back into the continuum. This is as good a place as any to step out from the incessant alternation, never yet ended and probably endless, between the particle and the continuum as the basis of thought about physics.

[7] "Hint" is the strongest word that I should use here, since the masses are so nearly equal that it was not possible to affirm with entire certainty in advance which nucleus was the heavier.

THE HUMAN SIDE OF SNOW

II. SPORT AND TRANSPORT

By Dr. J. E. CHURCH
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THE article on the "Human Side of Snow," which appeared in THE SCIENTIFIC MONTHLY, February, 1937, has at editorial suggestion grown into a series showing human adjustment to environments of snow and ice. The first article already published is "The Saga of Mount Rose Observatory."

The rapid progress in man's pleasurable adjustment to snow since the writer's first winter ascent of Mount Rose in 1895 in response to a challenge has made possible his recently uttered truism, "Then *I* was a 'damnfool'; now *all* are." Defense has become superfluous. Two million people annually seek the snow for pleasure, and mountaintops are scaled on ski. Snow-survey courses in the Western States alone exceed 750, with 14,000 snow-samplings. The original Snow-Survey Conference that was held in the West for snow-surveyors only has grown into three snow conferences covering the breadth of the United States and Canada and devoted to all the fields of interest of snow and ice, including the protection of fish and wildlife.

SNOW REMOVAL

Doubtless the first people to appreciate the advantages of snow and ice were the dwellers of the tundra regions around the Arctic seas, where summer travel inland was slowed by the soft turf and was confined largely to cruising along the shores. The winter increased both the range and the speed of intercommunication. Dogs and sleds were the key to mobility.

In the south where transport reached across and beyond the snow areas, road clearance, or in ship parlance canal building, was practiced. This was a gigantic effort but permitted continuity of wheel traffic with only slight interruption at intervals through the winter.

Snow removal has now become a highway function in 36 snow belt states. In 1939–1940, 232,615 miles of roads were cleared at a cost of $20,969,988.

In California last year snow-survey methods were used to determine the character and weight of the snow to be removed with a view to opening up an 11-mile stretch of highway over the crest of the Sierra Nevada to the southern end of Lake Tahoe. It was found that the amount was 163,000 cubic yards of snow, weighing about 34,000 tons, or 417 pounds per cubic yard.

In the State of Washington snow textures as well as snow depth have become a problem because of the variable climatic conditions that prevail.

J. D. MacVicar, maintenance engineer, Department of Highways, has found that west of the Cascade Mountains the snowfalls are quite generally loaded with moisture and the prevailing winds are tempered in severity. East of the Cascades the snow is much lighter and minimum temperatures in winter vary from zero F. to 30° below. Farther east in the state, however, the snow, being drier, drifts with only moderate winds following and even during precipitation.

Along the Columbia River Gorge, where the terrain rises abruptly from the river, various and unusual types of snow are found. In this area "graupel," or tapioca snow, being spherical, does not lie where it falls on the mountain sides but rolls down on the level cross-sections

of highways and railroads or at the foot of the cliffs.

At times, however, a heavy wet snow occurs of such large water content that it will not compact under traffic. Its removal *during* the storm period is very important as a slight lowering of temperature will cause a frozen slush which makes highway travel practically impossible.

Rainstorms when the temperature of the air is near freezing may form ice to a depth of two or more inches on the highways in a few minutes. To correct this condition the surface of the ice is striated and covered with sand. Any abrasive applied before the surface is striated is blown off as fast as spread.

Occasionally snow falls so dry and fine that it will not compact but is blown about like dust in the breeze.

The depth of the snow cover on highways through areas of maximum snowfall has proved to be less formidable than anticipated, for new snow is thoroughly removed after each storm and the snow cover rapidly settles.

In 1932, a year of normal snow depth in the central Sierra Nevada, the depth of the settled snow in the passes on April 1 was as follows: Tioga Pass (9,900 ft.) 6.7 ft.; Sonora Pass (8,800 ft.) 6.2 ft.; Carson Pass (8,600 ft.) 9.0 ft.; Donner Pass (7,017 ft.) 7.5 ft.

In the Cascade Range, at Snoqualmie Pass (3,019 feet) east of Seattle, Washington, the normal depth based on measurements over 15 years is 7.6 feet. However, depths of 15 feet or more are possible.

The removal of deep compacted snow in spring is more difficult, particularly if snow slides have occurred. In Chinook Pass, Washington, where the usual average depth of snow is about 20 feet, a power shovel on crawler treads removes the top course of about 10 feet. A bulldozer is then used to push back the remainder to the level of the road surface where the loosened snow is picked up by a rotary plow and blown clear of the sides. All snow plows are placed at strategic points and have a two-way radio communication with the outside.

Where both rains and freezing temperature occur the average density of the snow may be as high at 64 per cent., or 40.75 pounds per cubic foot. This is 1,100 pounds per cubic yard, or more than twice that of dry-laid snow.

For ice treatment on concrete pavements calcium chloride is mixed with the sand, but for bituminous pavements salt and sand are used.

In the Great Lakes Region, where the snow is relatively shallow and subjected to alternate freezing and thawing, the way of both maintenance men and motorists is hard. In Michigan, when road and weather conditions are bad or uncertain, a twice-daily forecast is issued. Northward, where the cold is steadier, the snow pavement may be superior to that of summer until the season of slush arrives, which fortunately is brief.

Drainage water from snow is a serious problem, particularly where it underseeps the road-bed or covers the road surface with glaze. Provision is now being made for snow storage with a drainage system to carry the water away.

The burden of snow removal is lessened where feasible by snow sheds and fences. When the snow is too deep to be controlled readily, railways are protected against blockage by snow-sheds, which, however, are usually unpleasant because they obstruct both light and view. On the Canadian Pacific Railway snow-sheds are sometimes of concrete and where feasible detours are built around them for summer use.

If the snow can be controlled, snow-fences are preferred even when high and complicated in pattern to meet the varying conditions of wind and slope. In the mountains of Norway the snow-fences are unusually high and in the uplands of

Winston Pote

SPECTATORS ON TUCKERMAN HEADWALL, MT. WASHINGTON, IN NEW HAMPSHIRE. THIS IS AN UNUSUALLY THRILLING COURSE FOR EXPERT SKIERS WHEN THERE IS "POWDER" SNOW. NOTE THE SKIER MAKING A FAST TURN NEAR THE TOP OF THIS WALL.

Sweden, where the wind over wide areas is unobstructed by forests, the height of the fences indicates the cumulative effect of wind and drifting snow. Only in the pine and fir forests do snow-fences become low or disappear.

The Japanese scientists have undertaken efficiency experiments by means of models of fences in a wind tunnel. Fine powder is used in place of snow.

They have found that "if there is a secondary fence behind the main fence at

THE SNOW PLOW IS DWARFED BY THE TOWERING WALL OF SNOW.

a distance of about ten times the height of the latter, a calm zone can be gained between them to prevent a cut there from being buried by drifting snow."

Where the drift snow is abnormally copious, the storage capacity of the fences can be increased by erecting additional panels upon them. In Wyoming, snow clearance in both railway and highway cuts has on rare occasion been desperate because of the cement of gravel and snow deposited by winds.

In these days of war emergency a most welcome snow remover for airports has been designed by John B. Sweeny, of the Allegheny County, Pennsylvania, Bureau of Maintenance, that "virtually burns away the snow." As described by *Engineering News-Record* (February 6, 1941):

> The novel equipment consists of a 7- by 10-foot wide box equipped with six burners fed by a mixture of crude oil and air from a 300-gallon tank-truck.
>
> On the first test the machine cleared a ten-foot wide path of three-inch snow, operating at a speed of six-miles per hour. A scraper attached to the front end of the steel box heating chamber removes deep snow and at the rear a wiper blade spreads out the water from the melted snow, thus helping the heated pavement to evaporate the water. It is estimated that an emergency-landing area, 150 feet wide and long enough to permit planes to land and take off, could be cleared with the machine in an hour.

Snow Travel

Sleds. Specialized snow transport is employed where the snow is continuous, but dual-use vehicles are being developed. Although other qualities are also essential, ability to traverse soft snow is prime. The goal of this development, however, is still distant and elusive.

The Arctic sled, like the kayak for water, has been most efficiently developed for strenuous conditions of snow and ice. So snow-conscious have the natives become that they have invented several terms for snow to designate its traversability, and so expert have they grown in controlling sleds on side slopes and declivities that they are proud masters of the craft.

Dogs are naturally the motive power, and the accompanying man power is sufficient to extricate the sleds when bogged. Where timber is thick, as at lower latitudes, the dogs are attached to a lead line, but on the open tundra and ice the dogs are individually attached to the sled and spread out in a broad fan within close reach of the driver.

Nevada Photo Service

WINTER SCENE ON ROUTE FORTY IN THE SIERRAS

THE WEATHER STATION OF THE UNITED STATES AIRWAYS, CAN BE SEEN IN THE UPPER RIGHT-HAND CORNER, OVERLOOKING THE SUMMIT OF DONNER PASS.

A loop of rope thrown over the forward end of the runner and dragging beneath it provides a brake. On steeper slopes the sled is allowed to run over the traces, thus reversing the position of dogs and sled, and the slower speed of the dogs serves as a back drag on the sled. The more knowing dogs lie down and are hauled thus to the bottom. The driver at the handles directs the speeding sled, the beat of his feet sounding like accelerating pistons.

On the inland ice of Greenland necessity forced sudden developments in transportation by the Michigan-Greenland Expedition when returning to base

Nevada Photo Service

LOOKING DOWN THE VALLEY TOWARD DONNER LAKE

THIS WINTER VIEW OF THE DONNER PASS ROUTE SHOWS THE SNOW SHEDS OF THE SOUTHERN PACIFIC RAILWAY ON THE MOUNTAIN TO THE RIGHT.

CUTTING A ROADWAY THROUGH STEVENS PASS
IN WASHINGTON STATE AT THE END OF A WINTER SEASON.

from its winter trip of 1927–28. The downslope winds had cleared the snow from the ice and destroyed traction for feet as well as sled. Descent was therefore effected by easing the sled by means of a cod-line paid out by two men whose joint weight behind a hummock served as a counterpoise. Fortunately the strength of the cod-line also permitted the lowering of the loaded sled down an abrupt ice-face that had been developed across the trail since the inward trip.

OPENING UP CHINOOK PASS IN WASHINGTON STATE

A surplus load of instruments and cameras was more readily hauled in a caribou tarpaulin suggesting an elongated seal with the fur side out to create friction on the ice.

Iceland ponies were used by Koch and Wegener in 1913 on their journey across widest Greenland where the snow was more stable, for ponies could also carry packs from the bare coast to the snowfields where sledging would begin. However, the sole surviving pony, courses. The snow is relatively shallow and offers little obstruction, but the river ice sometimes breaks under the weight. Airplanes flying the route keep sharp outlook and are readily summoned.

Of the same general character is the "Sno-Motor" developed by the U. S. Forest Service at Mount Hood and used by the Southern California Edison Company in the High Sierra. It consists of a broad single-tread caterpillar, steered by cables attached to a trailer snow-pon-

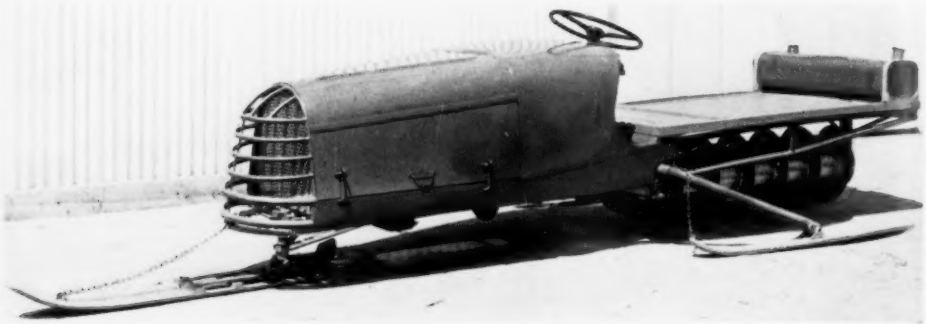
WINTER SCENES IN THE CENTRAL SIERRA NEVADA

Left: CLIMBING IN A WIDE-RUNNER SLEIGH ON THE ROAD FROM CARSON CITY, NEVADA, TO LAKE TAHOE. THE HORSES TRAVEL TANDEM AND SOMETIMES WEAR SNOWSHOES. *Right:* AN OLD PUSH-PLOW THAT WAS USED IN EARLY DAYS ON THE NARROW GAUGE RAILWAY TO TAHOE.

Grani, at the end of the traverse was unable to thread the crevasses where the ice descended sharply to the shore. The pet dog who kept pace with his master became a last meal before a chance boat from Pröven chugged past. Reindeer are doubtless economically superior to dogs where caribou moss abounds, as in Lapland and the barrens of British America and Alaska.

Near the end of the evolution of snow transport is the sled train drawn by a caterpillar tractor. Such trains bear heavy freight to the camps and mines of lower Canada, but are confined to definite routes along roads and frozen water toon. It can therefore traverse deep and relatively soft snow. From Huntington Lake to Florence Lake it carried 12 passengers and approximately a ton of freight up maximum grades of 55 per cent, and along side-hill slopes of 25 per cent. Snow depths varied from 3 to 12 feet. Its speed for the 30 miles including stops was 3 miles per hour. Its fuel consumption was 1¼ gallons per mile.

Of lesser power but greater adaptability are several motor sleds that offer runabout service for mail, snow-surveying and sport. They constitute an emergency means of rescue in the National Forests, where they can be readily



E. M. Tucker

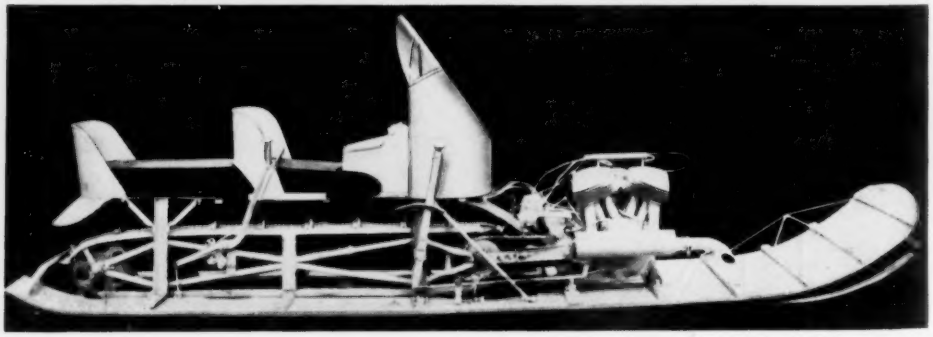
TUCKER SPIRAL-DRIVE SNOW SLED

THE DRIVING DRUM CAN BE DEPRESSED IN SOFT SNOW TO OBTAIN GREATER TRACTION.

transported by auto trailer to points of departure. Their motive power varies from the dual-use caterpillar through the spiral cylinder and "escalator" toboggan, to the air-propellor sled. The first seeks mobility where bare ground alternates with snow. The second is the well-known screw propulsion applied to snow. The third represents the combined use of the endless belt drive and the broad toboggan, the fourth seeks the air drive uncontrolled by the character of the snow.

All have their advantages and are being further refined particularly to meet the impediment of soft snow. The caterpillar sled, known as the Sno-Cat, under recent tests approaches the ideal requirements of buoyancy and traction where propulsion must be provided by the snow itself. Snow friction is eliminated except on the steering ski and the body is set high to permit the two driving belts to compress the snow to stability. Still greater height of bed is desirable where the snow is unusually deep and unconsolidated. This sled under favorable conditions is capable of attaining a speed of fully 20 miles an hour. The spiral cylinder of the second sled is acquiring a smaller drum with correspondingly wider spiral fin and broader ski. On the other hand, the toboggan sled is having its side runners decreased in width and the tractor belt correspondingly increased to obtain a more effective grip on the snow.

The "Sno-Plane" strangely was developed in the wild country of southwestern Colorado and has been success-



Four Wheel Drive Auto Co.

ELIASON MOTOR TOBOGGAN

IN WHICH SPEEDS UP TO FORTY MILES PER HOUR OVER UNCHARTED COUNTRY ARE POSSIBLE.

fully used by the U. S. Reclamation Service in the Jackson Lake region adjoining Yellowstone National Park. The small shelter cabin rides low on three duralumin skis, 1 foot wide and 7 feet long, the one in front functioning also for steering. To avoid injury to the propeller open trails must be used. On smooth packed snow, as on Jackson Lake, a high speed is possible. On sticky snow little resistance is noted because of the constant thrust of the propeller. The 150-mile snow-survey route that once required ten days for skiers can now be accomplished in two and can be made between storms rather than through them.

The individual net weight of these motor sleds does not exceed 500 pounds, thus permitting them to be manhandled when bogged down. Each one can carry two or more persons easily and draw a train of sleds.

Snowshoes. The type of snowshoe developed in various countries depends upon the density of the snow and the forest covering. In Canada, where powder snow and thickets abound, the webshoe of large area has long been popular. Where short turns are desirable the bear-paw shape is used despite its tendency to tip. In Norway the ski, or wooden snow skate, has reached high perfection because of the firmer snow and open country which afford opportunity for maneuvering and for high speed on down-slopes. Soft snow on hard unbreakable crust is the optimum surface for them. Specialized ski waxes now take the place of the former shellac and a deerskin undersurface serves as an aid in climbing. At Lake Tahoe a top speed on webs of 4 miles an hour could be attained if the snow was firm, but once after a snowfall of 3½ feet 14

Nevada Photo Service

ON SKI AT SUGAR BOWL SKI LODGE IN THE HIGH SIERRAS

THE SKIERS PRESENT A SHARP CONTRAST AGAINST THE BACKGROUND OF SNOW.

miles were accomplished only in 13 hours, a part of which was over a beaten trail. With ski at Jackson Lake, Bennett B. Hill, reservoir superintendent and snow-surveyor, has covered 19 miles in 19 hours but has also made 35 miles in 5 hours. These are cruising, not racing, speeds. The exhilaration of sitting on a pair of ski while landscape and home rapidly draw near is full compensation for a long day's climb.

In the Alps the Bavarian snowshoe, consisting of a small oval hoop with rope mesh, has been developed for mountain climbing where the crust is too steep for broad webs or ski and too thin for shoes and crampons. Both the rope and the edge of the hoop cut sufficiently deep into the crust to give firm footing even where only the side of the shoe has contact. On rocks where snowshoes are discarded for crampons, the former become a negligible weight and package on the back of the knapsack. In descending steep slopes the snowshoes prevent the impact of the foot from breaking through the crust with resulting injury or even fracture of the leg.

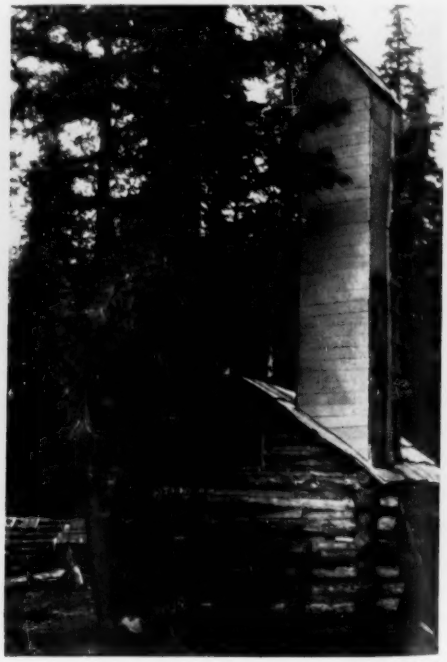
This type was used in the writer's early winter ascents of Mount Rose and Mount Whitney, but fell into disrepute in the softer snows of lower altitudes, the shoes being dubbed "postage stamps" and their tracks "postholes."

Because of their speed and sport value ski have become the dominant snowshoe, although their use is exacting a high toll of accidents and will continue to do so until skiers by their own public opinion insist upon skiing under complete control. A code of ski-ethics and ski-safety has been proposed in Crater Lake National Park by Ranger J. Carlisle Crouch (A. G. U. Trans. Part III, 1940) and the California Ski Association has established uniform Ski-Mountaineering Tests. The National Ski Patrolmen or Life-Guards of the Snow have

R. A. Work

SANTA CLAUS CHIMNEY

ON A SHELTER HUT WHICH IS OTHERWISE COMPLETELY BLANKETED WITH SNOW.



R. A. Work

THE SAME SHELTER HUT

IN THE CASCADE MOUNTAINS IN THE SUMMER, WHEN THE WHOLE HUT IS VISIBLE.

organized the N. S. P. S. (National Ski Patrol System) to safeguard winter mountaineers.

The chief cause of present accidents is the tight lashings that hold the ski so firmly to the foot that the ski has the effect of a giant wrench twisting the leg when a "spill" occurs. Lashings which will release the foot when the skier is thrown off balance have been designed and are on the market. They require greater publicity and willingness to try them. Serious accidents have happened even to forest rangers the past winter, which would have resulted in helplessness and fatal exposure had not companions been present. In one case the skier was unable to extricate himself from his ski. The other after continuing three miles on his injured leg was long marooned in a cabin until the snow became compact enough for sledging.

Snow Shelters. On the snowfields, snowshoes or sleds are as essential to the traveler as a boat on water, for without buoyancy or progress in either element one would quickly perish. Unless the trip is short, sleeping bag, tent or more permanent shelter becomes a haven.

The two absolutes in outdoor life are dryness and warmth. Freezing must be avoided. In the polar regions, snow in the furs or a "sweater" among the members of the expedition is a peril. One must not sleep in a wet bed or in sweaty clothing. The Eskimos keep their fur clothing well ventilated on a trek and strip before entering their sleeping bags.

But warmth is a relative term. Life grows sluggish and slow only at low temperatures, such as 30° to 40° below zero Fahrenheit, while it is comfortable somewhat below freezing. Above freezing the snow becomes wet and indoor heat of the normal type becomes sickening.

Shelters may be of any type. On Mount Rose the original shelter camp at

SLEEPING-BAG TREE AND SAND-BAG SHELTER CABINS
AT AN ALTITUDE OF 9,000 FEET ON MOUNT ROSE.

CAMP ON THE GREENLAND INLAND ICE

THE TOWN OF HOLSTENSBORG, GREENLAND, IN WINTER

9,000 feet consisted of two rabbit-skin sleeping bags left hanging from the limb of a giant spreading tree and lowered to the snow for use. If the warmth of the bags was insufficient, a covering of snow was shoveled upon them. To escape a gale of 70 miles per hour, which at zero temperature Fahrenheit withers the flesh, a "grave" was once dug in the snow for the bags. The next season a sandbag hut 3-men wide and half-a-man tall was provided with a large rabbit-skin blanket and a tiny oil cooker. The dog was perforce the pillow. Before sleeping, the oil cooker was extinguished, for it might be kicked over and the exit was small. Here storms of thirty-six hours were outstayed in comfort. A full-height sand-bag cabin was provided to permit one to stand erect.

Frequently it is possible to locate cabins where the ground is blown bare of snow, but sometimes the snow lies uniform and may reach depths far above the cabin roof. Digging either in or out is a severe exertion, providing the cabin can be found. Entrances therefore are provided in the peak of the cabins or a "Santa Claus" chimney is extended upwards—in the Cascade Mountains to heights of 20 to 30 feet—with a ladder inside for descent. The weight of the snow above the roof of the buried cabins has been measured by snow sampler at 12.5 tons. The area of the cabins was only 10 by 17 feet approximately. The supporting power of the purlins and shakes seems remarkable until the observer finally realizes that the snow by its own cohesion is supporting itself with only moderate weight on the roof.

One can even spend the night in the open in comfort without bedding if a fire can be built. In February during a trip along the crest of the range from Mount Rose Observatory to Lake Tahoe, the bed on the snow proved to be too narrow for three, leaving the writer to

PACK SLED UNDER DOUBLE CONTROL
ON THE MOUNTAIN-CREST TRIP FROM MOUNT ROSE.

sit by the fire, which was slowly melting itself into the depths of the snow. He soon followed the fire into the pit by making a gridiron of three limbs from nearby scrub and stretched out cozily, dropping an occasional piece of wood upon the fire as it sank deeper beneath him. Toward morning one of the members in the bed eagerly exchanged the bed for the fire and called the chimney bunk good.

Tents of any kind will suffice if light and adaptable. On the winter ascent of Mount Whitney, a "cowboy tent" resembling a torpedo was used to enclose the sleeping bags at night and was stretched out as a tarpaulin shelter against falling snow by day. At Lake Tahoe a "silk tent" with water-tight floor was hung from the branch of a tree. Later a cabin cruiser was developed for transport and shelter.

On the Greenland inland ice in winter a waterproof tent with snow floor was

A WHARF OF ICE AND SNOW IN GREENLAND

used. The tails of the tent were skillfully buried in snow and when reinforced by the sled and a rampart of snow blocks resisted a gale of 150 miles per hour that left the ice stripped of snow. Unfortunately, the impervious tent confined the vapor which became hoar frost on the walls and fell upon the furs at every vibration by the wind. A snow igloo would have absorbed the moisture, but the snow was too shallow to provide a dugout or even blocks for walls. The ice was impenetrable with the tools at hand and the task of excavation would have been exhausting. Where the snow is shallow the Eskimos use a pervious muslin tent for shelter and a similar case for their caribou sleeping bags to permit the outward passage of all moisture.

The importance of dissipating moisture was driven home to the writer when he insisted upon inserting an arctic-hare sleeping bag into his caribou bag for greater warmth. For three nights he was as warm as the proverbial bug but spent the fourth night massaging his stinging feet. Every toe turned blue and ultimately lost but regained its nail. Body moisture had formed frost in the fur and the lamps were too weak to dry either boots or bed. The inner, lighter bag was therefore discarded for independent use the next spring when the ice was melting on the inland lakes and the geese were nesting on the shore. Heavy socks, however, became a consolation throughout the winter nights. Dogskin inner boots required no socks during the day.

The peril of freezing perspiration was even more obvious in two earlier incidents. One evening in the early winter cold legs and feet drove the writer at top speed up the trail to the observatory for warmth, where he found his rubber packs lined with ice. They were promptly discarded for native boots. The rubber even when dry became hard in the cold and the rubber bulb of the camera sounded like ivory. Later for our winter trip to the inland ice, Marius Kleist, our native companion, prepared a wind-breaker suit from the remnants of a waterproof tent. On the very first day after a strenuous climb with dog-team up the ice front he returned with his clothing lined with ice. His tattered denim suit was immediately substituted for the other with complete comfort during the remaining weeks of the trip.

Nature sometimes exacts a higher price but usually is kind. Thus, early in winter mountaineering it seemed prudent to test the warmth of a rabbit-skin sleeping bag before venturing on a winter trip up Mount Whitney, being taken solely to shock the Californians into the realization that snow outings could do them no harm. The writer therefore spent a night in his bag on the open snow with a sheet thrown over his sled as a breathing tent and his feet encased in felt boots. The temperature was approximately 20° F. below zero. Ice needles from his breath fell from the tent onto his face and his feet became sticks but regained pliability next morning with walking. From the experience came immediately a kangaroo feather-pillow for the bottom of the bag into which to insert the two feet for mutual warmth in place of individual felts that would probably be damp from the day's use.

When caught once by the Arctic night in a tent without fire or sleeping bag he rolled up in a caribou skin so small that head and feet projected but forced himself to wake at intervals to be sure his feet were not freezing. He was fortunate to have reached even this camp, for the next tent equipped with fur beds was found partially submerged and frozen by the "weeping" from the ice front. The bed looked cozy from above but was as inaccessible as a fish in a cake of ice.

Precautions must ever be taken. Escapes have too often been narrow and victims now come from the air as well as the snow. A forced descent from an airplane upon the snowfields this past winter has now caused a movement to place the name of the mountain huts upon the door with direction to nearest habitation. Blazes can readily be made from discarded auto-license plates. In ski and snow survey areas, a toboggan with web snowshoes should be cached in each hut with two-way radio where feasible. Ski have proved entirely inadequate for hauling a toboggan in soft snow with a person upon it. When once bearings have been determined, the direction can be maintained even in storm by sighting from the rear and thus preventing the line of march from curving. Snow goggles must be used when the sun is above the horizon, for the reflecting power of clean fresh snow is intense. The reflected heat of the sun from it may be as high as 87 per cent.

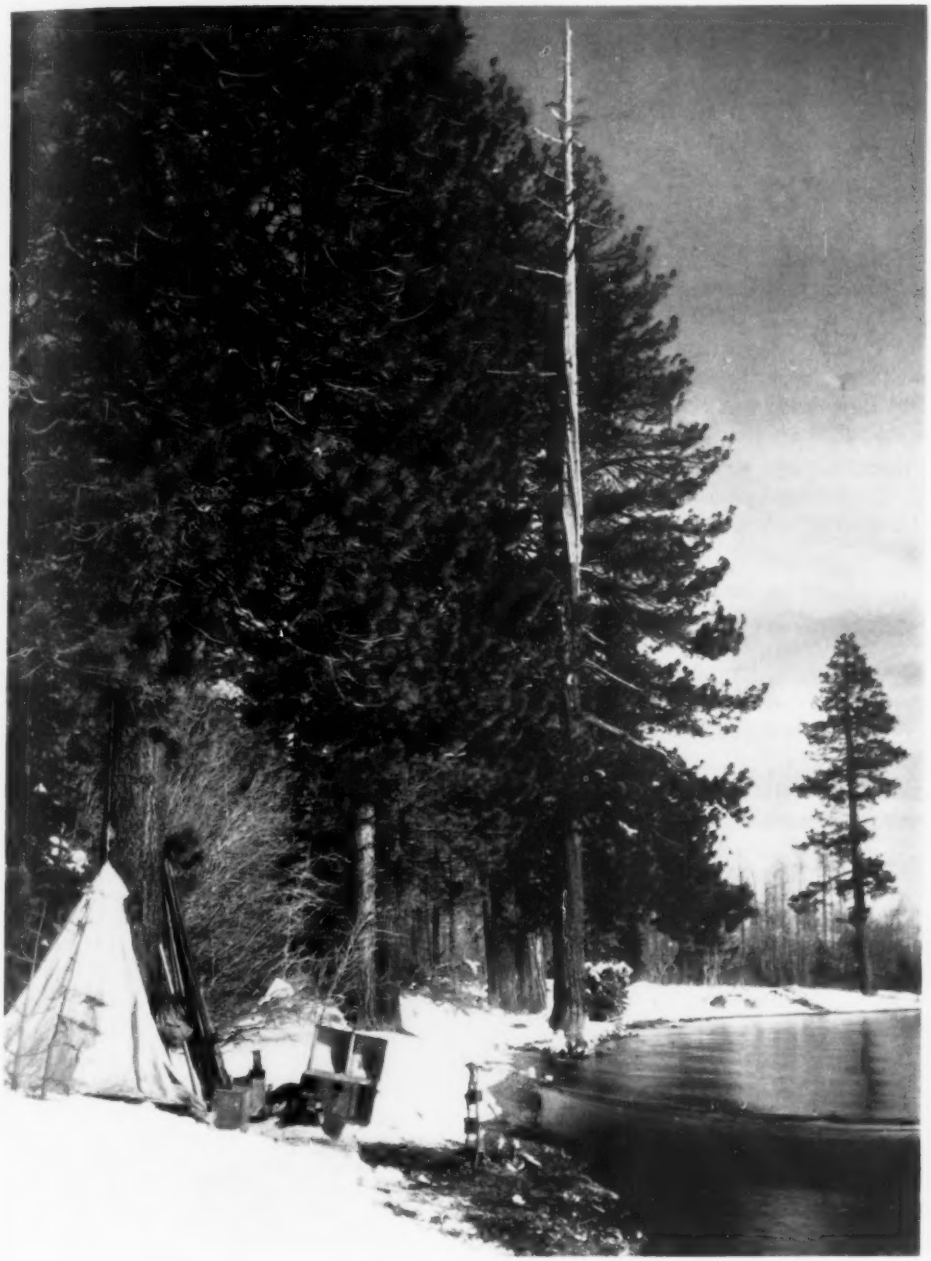
A quarter century or more ago the writer suggested a chain of ski huts a day's journey apart up the western slope of the Sierra Nevada to the crests and a winter trip by sled, cruiser and ski along the snow-clad shores of Lake Tahoe and Fallen Leaf Lake to the summit of Mount Tallac, after the manner of the Dartmouth ski huts in the White Mountains and the week-end "bunk and boarding" train for skiers from Stockholm to Lapland. Instead snow-bowls with ski-lifts and moderate-price shelters have sprung up everywhere. New Hampshire publishes a "Winter Map" each year. The "Stream Liner" bears Chicago skiers to Sun Valley, Idaho, and the Central Vermont Railway runs a weekly ski-train known as the Ski Meister to Mount Mansfield from New York and Boston. There "the world's longest and highest chair-lift in the world" has been completed. The lift, which has a horizontal length of 6,330 feet and a vertical height of 2,030 feet, is capable of handling 200 passengers per hour.

Ski forecasts are issued by bulletin, press and radio. These are vital in the East where cross-country runs are limited and the texture and depth of the snow are changeable. Community singing at railway points of departure provide the "sleighbells."

Airplanes. The Arctic and particularly the Antarctic have become the proving ground of snow transport of all kinds. Peary and Amundsen attained the geographical poles with sledges. The Scott Expedition followed. Gould closed the series of long sled journeys. Byrd and Amundsen-Ellsworth flew to the poles without landing, the former visiting both poles and the latter spanning the Arctic.

Earlier Amundsen-Ellsworth had landed on and risen from the Arctic icefloes with an airplane. Later Wilkins made a landing on his flight over the Arctic Ocean from Alaska to Spitzbergen, and Ellsworth made several on his flight over the Antarctic icecap from Palmer Land to Little America on Ross Sea. Shorter flights with landings were made by Gould and Byrd in Antarctica and flights on the snow have now become established despite possible gales. In the Arctic, the Soviet explorers under the leadership of Professor Otto J. Schmidt have flown almost at will to the North Pole and in May, 1937, established a floating polar meteorological station, the members of which were taken off their melting icefloe the following February in the Greenland Sea. Soviet fliers have even hopped the Arctic hemisphere from Moscow to Southern California.

For the local work of snow surveying in regions difficult of access, Horace P. Boardman, chairman of the Nevada Cooperative Snow Surveys, foresees the early use of the helicopter, which can descend and rise in narrowly restricted areas and await the convenience of its



SNOW SURVEY CAMP ON THE SHORE OF LAKE TAHOE

THE LAKE NEVER FREEZES AND THEREFORE AFFORDS READY TRANSPORTATION BY BOAT TO ALL POINTS ON ITS SHORE LINE OF SEVENTY-TWO MILES.

passengers. The cost may not greatly exceed that of motor sleds.

But a final effort is being made to develop wheel traction on the snow. For the recent United States Expedition to Antarctica Dr. T. C. Poulter developed a snow pontoon with retractable wheels for sliding over crevasses. It was believed that the 10-foot rubber tire wheels would obtain traction before sinking too deep in the snow, but the powder snow of the Antarctic gains density only slowly with depth and cuts deeper beneath the spinning wheels. An endless belt like that of a caterpillar tractor if made sufficiently wide would provide a far greater area of support on the snow without possibility of the snow being cut out. The sand dunes of Lake Michigan, where a favorable test was made, seem to be denser than the Antarctic snow and more resistant to cutting. The tendency of rubber to disintegrate under movement below $-60°$ F. can be avoided by using the cruiser only in summer when higher temperatures usually prevail. The size, cruising radius and auxiliary airplane make the cruiser desirable, but it would become helpless to extricate itself if it ever bogged, and such occasions might be frequent. Dr. Poulter, however, believes that a shift in gear ratio would solve the problem. Meantime, the cruiser awaits a further expedition for its ultimate test.

But initial friction on airplane ski still causes trouble where heavy loads must be raised into the air from a state of rest, and its avoidance has long been a subject of discussion and experiment. Where the temperature of the snow is moderate and the crystals are round, the friction is slight. But when the temperature is low and crystals are angular the friction may approximate that of sand. Likewise, water-soaked snow because of its continuous film of water and surface tension may be adhesive. Koch and Wegener state that in Greenland at temperatures of about $-4°$ F. ski refuse to run.

THE CABIN CRUISER *MOUNT ROSE*.

In Canada, where airplanes must depend upon ski for landing and take-off, the Canadian Research Council through G. J. Klein has made prolonged tests with valuable results. Observation was had of the contact zone between ski and

MIRROR LAKE BASIN, MOUNT WHITNEY.

snow by a glass window through the body of the ski, while their drag was being instrumentally recorded. His comments are as follows: "The highest sliding resistances measured occurred when the snow was slightly wet and still retained its needle-like structure, but upon losing the latter its sliding resistance was low. Still higher resistances would probably have occurred at very low temperatures."

He suggests therefore that the contact between the ski and the snow takes place at a large number of small areas and that sufficient heat is generated by surface drag to provide water lubrication. The surface drag is then made up of (*a*) solid friction, (*b*) viscous drag due to shearing in the thin film of water and (*c*) drag due to surface tension effects of drops of water which enclose each small area of contact. The proportion of each factor will vary for different conditions. It was estimated from observation that the total area of contact was of the order of 20–50 per cent. of the area of the ski bottom at unit loads of 200–500 pounds per square foot.

The surface tension is therefore large. During sliding this force does not act normal to the ski bottom since the leading angle of contact is greater than the trailing angle.

Decreasing the wetted area, *i.e.*, increasing the unit loading, seems the only method of decreasing sliding resistance in very wet snow.

Five recommendations are made for improving the snow characteristics of ski under all conditions:

A material which resists wear, has a low tendency to wet and which gives low surface tension drag is required. Of the materials tested, Bakelite fulfils all three requirements most satisfactorily.

High unit loading improves the snow characteristics of skis under all conditions. A unit loading of between 400 and 500 pounds per square foot is recommended instead of 200 pounds per square foot, which is the present general practice.

The ratio of length to breadth should be at least 6. High ratios are particularly important for highly loaded ski and low temperature snow.

Flexible construction assists "unsticking."

The maximum angle of the bow should be between 20° and 25°.

The partial success previously attained in clearing airplane-wings of ice seems now to have been made complete by means of a simple invention by Russell S. Colley. He points out (Bull. Amer. Met. Soc., April, 1941) "that the inflatable shoes, which are attached to the leading edges of air-plane-wings, are effective where they are alternately inflated and deflated. However, it is necessary to have non-extensible strips to hold the edges of the shoes. Since only a small edge, or a sudden change in contour, is enough to cause ice to accumulate, it may form on these strips. The invention provides for an additional inflatable strip to go over the edges of the shoe. The front of the extra strip moves with the large one while the back of it is attached smoothly to the wing, and no ice may form."

A half century of endeavor is bringing its solutions. Snow and ice are no longer insuperable obstacles to man and their once sinister aspect has become a source of appeal. Whether we move over the surface or fly far above the snow-clad peaks, the last and farthest regions of earth are now within our reach.

THE DISCOVERY OF PINACATE VOLCANO

By RONALD L. IVES

BOULDER, COLORADO

HISTORIES of geology usually credit the recognition of extinct volcanoes far from present volcanic regions to Jean Guettard (1715–1786) and Nicholas Desmarest (1725–1815), whose thorough studies of the ancient volcanoes of Auvergne have not only become scientific classics, but form the bases of the modern science of volcanology. A few of the more thorough works justly credit Strabo (63(?) B.C.–21(?) A.D.) with the observation that Vesuvius, inactive at the time of his visit, was a volcano.[1]

Recent studies of manuscripts in the archives of Mexico, largely initiated by the work of Herbert E. Bolton, have disclosed three narrative accounts of an exploration of the Sonoran desert region in 1701, during which the Sierra de Santa Clara, now known as the Pinacate Peaks, was correctly recognized as a formerly active volcano.

Since the beginning of the present century, the Pinacate region has been studied by workers in several fields of science, and the findings of this early expedition found quite accurate. Location and immediate geographic environment of the Pinacate Peaks are shown in Fig. 1, an outline map of the Arizona-Sonora boundary region.

The diaries of the three literate members of this expedition, all of which are literally "mines of information," did not come to the attention of English-speaking scholars until about a generation ago, and only one of these has as yet been translated into English.

Pertinent excerpts from these narratives, which together constitute a fascinating "lost chapter" in the history of North American geology, will be here presented, together with condensed biographical notes, under the names of their respective authors, and will be followed by a brief résumé of subsequent explorations in the same area.

[1] Archibald Geikie, "The Founders of Geology," New York, 1905. "Strabo," pp. 18–20: "Guettard," pp. 104–139: "Desmarest," pp. 140–175.

EUSEBIO FRANCISCO KINO, S.J.

Born near Trent, Tyrol, August 10, 1644, Eusebio Francisco Kino, later to become the "Apostle to the Pimas," received his early education at Ala. After further study, at Ingolstadt and Freiburg, he entered the Jesuit Order in 1665, taught grammar for three years, and became locally famous as a mathematician. In answer to a call for missionaries, Kino came to the New World in 1681, and labored for several years in Lower California. Assigned to Pimería Alta (now northern Sonora and southern Arizona) in 1687, he spent the remaining 24 years of his life Christianizing, exploring and mapping that "so sadly watered vineyard of the Lord."

Chief among Kino's accomplishments are the rediscovery[2] that California was a part of the American mainland, and not an island[3]; the production, with crude instruments,[4] of a satisfactory map of Pimería Alta; and the exploration of a route from Sonoyta (Fig. 1)

[2] Earlier evidence of the non-insularity of California, found by Melchior Diaz in 1540 and Juan de Oñate in 1604, seems never to have become generally known.

[3] H. E. Bolton, "Kino's Historical Memoir of Pimería Alta," Cleveland, 1919.

[4] Kino's instruments, as determined from his diaries, consisted of a sextant, compass and telescope. The map appears as frontispiece in Bolton, *op. cit.*, I.

to the Gila, now known as the Camino del Diablo (Fig. 2),[5] and adequately marked by "three graves to the mile." Kino's terse narrative, condensed from Bolton's translation, follows:

On the twentieth (of March, 1701), Palm Sunday, having said the two masses . . . we set out for the west; and after covering six leagues of road, although level, and along weathered rocks like slag which long ago had been thrown out by this mountain or volcano of Santa Clara, which we passed on our right or to the north, we arrived at another tank of water shut in between rocks,[6] with very little pasturage; and ascending to a neighboring little hill, we descried California very plainly, to the west and southwest, and afterwards the soldiers also and all the men sighted it.

[5] Literally, "The Devil's Road." History and topography adequately described by W. J. McGee, "The Old Yuma Trail," *Nat. Geog. Mag.*, Vol. 12, 1901, pp. 103–107, 129–143.

[6] Bolton, using Lumholtz's maps and field data, identifies this tank with the modern Tinaja de los Chivos (indicated in Fig. 1 by the letter *T* southwest of the Pinacate Peaks). Field work in the same area by the writer confirms this identification.

Juan María Salvatierra, S.J.

Contemporary, close friend and often traveling companion of Kino, Juan María Salvatierra was born in Milan in November of 1644. After studies at Parma, Salvatierra became active as a Jesuit missionary in Mexico in 1675, and was appointed *Visitador* of Pimería in 1690. Instrumental in the founding of the mission at Loreto, Lower California, famous for its bells and pearls, Salvatierra, with the active cooperation of Kino, maintained the ecclesiastical settlement on the arid and poverty-stricken peninsula until his death, from age, illness and over-exertion, in 1717.

Salvatierra's work is not as well known as Kino's, but the available records clearly show that his explorations, a part of his missionary activities as were Kino's, were of considerable scope and importance. Had Salvatierra been a less competent administrator, it is probable that his geographic contribu-

FIG. 1. MAP OF SOUTHWESTERN ARIZONA

GENERALIZED OUTLINE MAP OF SOUTHWESTERN ARIZONA AND NORTHWESTERN SONORA.

FIG. 2. THE CAMINO DEL DIABLO

A SCENE ALONG THE CAMINO DEL DIABLO ABOUT TEN MILES WEST OF SONOYTA.

tions would have been greater. Salvatierra's interesting narrative, translated from the printed Mexican version,[7] follows:

> . . . and we left (San José de Ramos[8]) guided by Indians who went after salt, giving us in more detail the trail to the sea.
>
> On climbing a hill a league distant from San José de Ramos, on the flank of the hill of Santa Clara, we found a horrible country, which seemed more like cinders than land, and all of it scattered over with rocks and fragments, all black, and shaped as pitch which has been spilled and run out and become solid. Thus in ancient times a horrible flow of volcanic material left the hill of Santa Clara, which has all the marks of having been a great volcano. It gave us more horror to discover eight leagues from here a great chain of mountains which seemed also to be made of cinders, so that I do not know where there is a place in which can be better shown the face of the earth in the general conflagration before judgment day. We were much more frightened by the extended range in front of us, for here we will have to cross on the coming day. We travelled six leagues, and were guided to a water hole named by the natives *aybacusi*.

[7] J. M. Salvatierra, "Letter to Francisco de Arteaga," Documentos para la Historia de Mexico, Ser. IV, Vol. 5, 1856 (?), p. 146. Original manuscript probably written about 1702.

[8] San José de Ramos is a waterhole in the usually dry bed of the Sonoyta River just south of the present Batamote Hill. For location see map accompanying Carl Lumholtz, "New Trails in Mexico," New York, 1912.

Captain Juan Mateo Manje

Guarding Kino and Salvatierra on several of their journeys into unknown lands was Captain Juan Mateo Manje, commandante of the presidio of Fronteras. His major literary work, "Luz de Tierra Incógnita," still untranslated, contains little direct biographical material, but indicates, by its style and context, that Manje was not only a keen observer, but was educated and well read. In many instances, primitive customs, legends and religious beliefs, usually unnoted by Kino and Salvatierra, are carefully described by Manje.

From information collected by Bolton during his exhaustive study of the Kino manuscripts, it is learned that Manje was a nephew of Domingo Jironza Petrez de Cruzat, governor of New Mexico from 1680 to 1686 and 1689 to 1691. In 1693, Manje was appointed ensign in the newly formed Compañia Volante de Sonora, and rapidly advanced, being referred to as General in 1703. Hs was still commander of Fronteras in 1720, but apparently died before 1732, when Juan Bautista de Anza, Sr., father of the founder of San Francisco, took charge.

Manje's narrative, translated from the printed Mexican version,[9] follows:

> On the twentieth (of March, 1701) we went toward the sea, with three Indian guides, travelling westward always over rocks and mal pais[10]

[9] J. M. Manje, "Luz de Tierra Incógnita," Mexico, D. F., 1926, p. 286. Original manuscript dated 1720.

[10] The term *mal pais*, often corrupted, literally meaning *bad country;* used in the southwest to designate lava beds.

and crags and hummocks [Fig. 3]. We went eight leagues, coming to the shoulders of the peak of Santa Clara, where we halted at a place called El Tupo,[7,11] with scanty pasture and a natural tank of rain water, from which the horses drank, in a dry wash full of rocks and hummocks.

On these two trips[11] were seen hills and mountains and canyons of melted rocks, similar to the slags which leave silver when it is refined in a retort. This flux, which the Indians call temesquitate,[12] and cinders extend for many leagues from the vicinity of the aforementioned peak.[13] We believe, and this seems probable, that this was a volcano, which lasted some years, and resulted from the concentration of a great combustible mass of sulfur and niter in an underground cavity. This was greatly ravaged, after which, lacking the store of material from which came the beginning of the fire of its formation, the voracity of the combustion ceased, and the materials became fused into this abundance of canyons, hills and mountains, ravaged as we have seen. It is probable that this lasted some centuries, as testify other volcanoes of Europe and those of the two Americas, whose subterranean fires, according to Padre Atanacio Quirquerio,[14] distinguished mathematical philosopher, have lasted four or five centuries, and at times the force and impetus of the materials have become so great that they have broken loose, and great rivers of fire have run out, as those of Vesuvius, and Etna or Mongivelo.[15] In our own times there has flowed from the source a great river of fire, which ran with some speed to the sea, causing it to retire, and depositing, from this copiousness of melted material, a great plain of fragments in the gulf and (on the) sea bottom.[16]

[11] The other trip was November 6, 1699. Bolton, *op. cit.*, p. 207.

[12] Temesquitate is probably a Spanish rendition of the Nahuatlan *temetztliatle*, derived from *temetztli* = lead (*tetl* = rock or stone, *metztli* = moon) and *atle* = nothing from or instead of. Nahuatlan mineral names strongly suggest a fairly advanced knowledge of metallurgy. Another example is tepustete, Spanish rendering of *tepuztliatle*, primitive name for *gossan* (derivation, *tepuztli* = metal + *atle*).

[13] See Fig. 1, "Pinacate Lavas."

[14] One of history's unknowns, no trace of whose writings can be found by the Library of Congress.

[15] Mongivelo is a Spanish rendering of the old Italian name for Mt. Etna—*Montgebello*—compounded from the Italian *monte* = hill or mountain, and the Moorish *gebel* = hill or mountain.

[16] This is apparently a reference to the eruption of Vesuvius on December 16, 1631.

FIG. 3. FACE OF A LAVA FLOW

NEAR THE PINACATE LAVA PLAIN, SOMETIMES TO-DAY CALLED "THE SEA OF BROKEN GLASS."

FIG. 4. RIM OF A TYPICAL SMALL CRATER
RISING ABOVE THE EXTENSIVE PINACATE LAVA PLAIN.

FIG. 5. A TYPICAL PLUNGE-POOL WATER HOLE
TINAJA DE CARLINA, NORTHEAST OF PINACATE PEAK.

Thus appear to have come about the hills, mountains and valleys of melted rocks which we have seen. (They were) transformed from this flux which descended from the summit of Santa Clara mountain, where can be seen a depth and profundity which causes terror and fright[17] [Fig. 4].

Here, on another occasion, Padre Eusebio Kino climbed to survey the sea, whose waves seemed to beat at the brow of the hill, but he was deceived, for it is more than nine leagues to the sea, where he saw its beaches, dunes, and waves.

belief, as well as the emotional reactions provoked by the chaotic terrain, are outlined by Salvatierra; and the field evidence, accompanied not only by graphic analogies but by an attempt to explain the mechanics of volcanism, is given in some detail by Manje, whose other writings suggest that he was greatly interested in rocks and minerals.

FIG. 6. LAST DEPENDABLE WATERING PLACE IN THE SONOYTA VALLEY
AGUA DULCE. THIS SITE, THEN OCCUPIED BY CANEBREAKS, WAS NAMED BY KINO "EL CARRIZAL."

Verifications

From the context of the three narratives just presented, there can be no doubt that Kino, Salvatierra and Manje believed that the Sierra de Santa Clara, now known as Pinacate Peaks, was of volcanic origin. The reasons for this

Kino again visited the Pinacates in November of 1706, accompanied by Fray Manuel de la Oyela y Velarte, Alférez Juan Matheo Ramires and Juan Anttonio Duran. Leaving Duran, who was ill, at a water hole near the base of the peaks (Fig. 5), the rest of the party climbed to the summit, and verified Kino's previous observations regarding the peninsularity of California.

Between 1706 and 1882 there is no indisputable record of any visit to the Pinacates, although numerous Papago salt-gathering expeditions undoubtedly

[17] Although the source of the recent lavas at Pinacate was quite definitely a secondary crater between the remnants of an ancient crater wall, the largest calderas, view of which might logically cause *terror y espanto*, are north of the mountain mass, in the lava plain.

crossed the lavas on their traditional trail, worn into the volcanic glass by uncounted thousands of bare feet. It is possible that Francisco Garces, in October, 1771, stopped at Papago Tanks, on this old trail, during his transit of the desert between the mouth of the Colorado and Sonoyta, but the record is by no means clear. Indefinite legends, and the finding of bones and remnants of clothes by local Indians, indicate that emigrants passed near Papago Tanks

FIG. 7. RECENT ASH BEDS
NORTHEAST OF PINACATE, SHOWING CRUDE AEOLIAN BEDDING. PROBABLY DEPOSITED IN PRE-COLUMBIAN TIMES; ACCORDING TO LEGENDS, THE TRIBAL DEITY BUILT TWO FIRES ON THE PEAKS AND "THE ASHES BLEW ALL OVER THE EARTH."

some time between 1840 and 1870, perhaps in 1850, during the California gold rush, but further data are lacking.

In 1882, Sr. Y. S. Bonillas, a mining engineer of Nogales, visited the Pinacates, and discovered one of the great calderas for which the region has since become famous.

The first extended exploration of the Pinacates in modern times was that of the MacDougal-Hornaday party of 1907. This study led to the construction of an accurate map by Godfrey Sykes, to a survey of the botanical and zoological features of the region and to a quite definite verification of the findings of Kino, Salvatierra and Manje. Members of this party also produced the first series of photographs of the craters and lava structures of the area.

Two years later, Carl Lumholtz, ably assisted by Alberto Celaya, spent some time in and near the Pinacate Region, following, unknown to him, almost the same trails that Kino used more than two centuries before. From the notes collected by Lumholtz and Celaya, the Kino itineraries were worked out by Bolton (Fig. 6), and within the last decade, Lumholtz's map has been used in determining the route of the new railroad now under construction between Mexicali, Lower California, and Santa Ana, Sonora. Lumholtz's descriptions at times agree with those of Kino even to the descriptive analogies used.[18]

Recent studies in the Pinacates, largely the work of the present writer, have produced no major new discoveries, but show quite plainly that the pioneer work of the expeditions headed by Kino was of a high order of accuracy. Geologic and physiographic studies in the vicinity of the Pinacates indicates that the major volcanic activity there took place during the early Pleistocene, and lasted for many millennia. Since man came to the desert country, not more, and probably much less, than 4,000 years ago, there has been one great eruption of Pinacate Volcano, concerning which

[18] Alberto Celaya, who accompanied and assisted Lumholtz during the major part of his work in Sonora, has since settled in Sonoyta, serving several terms as *Comisario*. The assistance so generously given by him to every scientific worker who has passed through the little Sonoyta oasis has very materially increased the world's knowledge of the Sonoran Desert region.

the Papagos have a strikingly accurate legend[19] (Fig. 7); and one very minor eruption (January, 1935), the surface evidence of which has already (1940) been removed by wind and sheetflood erosion.

Conclusion

The narratives of Kino, Salvatierra and Manje show beyond any vestige of a doubt that these early explorers, during the progress of their missionary work, recognized the volcanic origin of the Pinacate Peaks. Whether this identification was independently arrived at by the three narrators, or was a "group enterprise," can not be definitely ascertained from the accounts.

Subsequent studies by a number of workers, at a much more advanced stage in the development of the science of geology, have shown that the observations contained in these diaries of exploration are not only substantially correct, but are far in advance of their time.

This identification of an extinct volcano in 1701 appears to be one of the first, if not the first, of such reports from North America, so far as can be determined from available literature, and antedates the publication of the works of Guettard and Desmarest, frequently called the pioneers of volcanology, by about half a century.

It seems somewhat ironic that Pinacate (Fig. 8), first recognized extinct volcano in North America, will probably be among the last of such structures to be studied in detail; but in this desert region, where even the modern inventions of sheet-iron canteens and steel-armored boots are of little avail against a malevolent and parsimonious nature, many of those who cross the boundaries of the Pinacate country—the waterless, grave-lined Camino del Diablo; the desiccated and caliche-baked bed of the Sonoyta River; and the shifting squeaking sands beside the unvisited red waters of the Gulf of California—heading toward the multicolored peaks rising like islands from "the sea of broken glass," cross them only once, and are heard of no more.

FIG. 8. THE PINACATE MASSIF, SEEN FROM DRY BED OF SONOYTA RIVER NOT FAR FROM KINO'S OLD CAMP AT EL CARRIZAL.

[19] R. L. Ives, "Geologic Verification of a Papago Legend," Masterkey, Vol. 9, 1935, p. 160.

STRUCTURE OF CELLULOSE AS REVEALED BY OPTICAL AND X-RAY METHODS[1]

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THE experimental and analytical procedures by which the modern ideas on the structure of cellulose have been established furnish an illuminating example of how various physical methods may contribute to the determination of a structure beyond the scope of direct observation. While optical effects and chemical evidence have been employed in disclosing the crystalline-micellar structure of cellulose, a large step toward a final, dimensionally definite theory was taken with the application of x-ray diffraction data. The study of the structure of cellulose has been pursued with considerable vigor, not only because it is, as Cross and Bevan have remarked, "the structural basis of the vegetable world," but also because it is technologically and economically important. For example, we need merely to note that cotton, cleaned and purified, is about 99 per cent. pure cellulose.

Cellulose is obtained solely from plant materials, but is used in a variety of artificial products made by chemical and physical processing of such materials. In some of the natural plant materials and derived cellulose products there are relatively large regions in which the chain-molecules of cellulose are well oriented, while in others the arrangement of the chains is random. In the native state cellulose is associated with various impurities, and in many of the manufactured cellulose products it occurs chemically modified. This discussion, however, is limited to those properties and structure which generally characterize cellulosic materials. The cotton fiber has been selected as a typical example of true cellulose for reference purposes, but some of the data which are cited have been obtained on other cellulosic fibers.

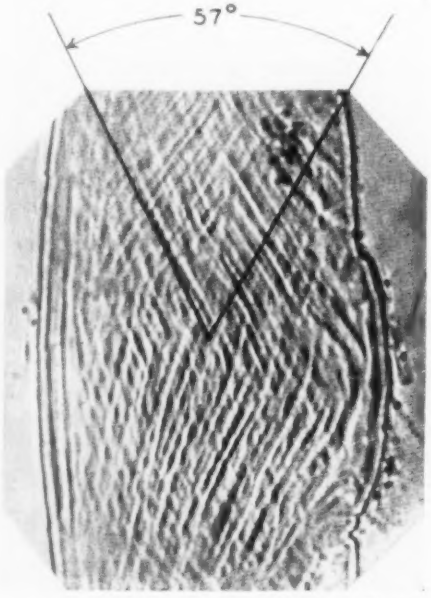
[1] Lecture presented in part before the annual meeting of the New Orleans Academy of Sciences on March 28, 1941.

I. OPTICAL STUDIES

The first critical observation made with a physical instrument on a cellulosic material probably occurred when some one viewed a plant fiber under a microscope. Such an observation, made on a cotton fiber with a modern microscope, is shown in Fig. 1. The photomicrographic magnification is of the order of 500 to 1,000. The hollow, central lumen of the fiber is obscured. However, the alternately spiraling fibrils, the first subdivision in native cotton cellulose, are clearly evident. The fiber illustrated was swollen to bring out the fibrillar structure, and the angle between adjacent or neighboring laminae of fibrils has been measured. The axis of the fiber is vertical. If such an observation as this were made with a polarizing microscope, *i.e.*, one containing a Nicol polarizer and analyzer, it would be found that the fiber is birefringent (doubly refractive). With a monochromatic light-source it would be found that the intensity of the transmitted light varies, depending on whether the vibration-plane (the electric vector) is parallel or perpendicular to the fiber axis. If, on the other hand, illumination with plane-polarized *white* light were used, it would be found that

the fiber is generally colored, and that this coloring changes as the fiber is turned through 90 degrees on the microscope stage. This is the so-called dichroic effect. Without the necessity of referring to the theory of either of these effects, it is immediately evident that the fiber is optically preferential as concerns direction, *i.e.*, anisotropic. A further conclusion may be reached, namely, that the *cellulosic material* of which the fibrils are composed is anisotropic. The approximate parallelism of the fibrils to the fiber axis, if these fibrils were not composed of an anisotropic substance, could not account for these optical effects, since the fibrils are much too large compared to the wave-length of light.

Nägeli recognized this anisotropy, and about 80 years ago advanced the first theory of crystalline micelles to explain the optical effects.[2] His theory led him



Courtesy of W. A. Sisson.

FIG. 1. PHOTOMICROGRAPH OF A COTTON FIBER, SHOWING ORIENTATION OF FIBRILS. FIBER SLIGHTLY SWOLLEN IN PHOSPHORIC ACID.

[2] Cited by A. Frey Wyssling, *Science Progress*, No. 134, 249, 1939.

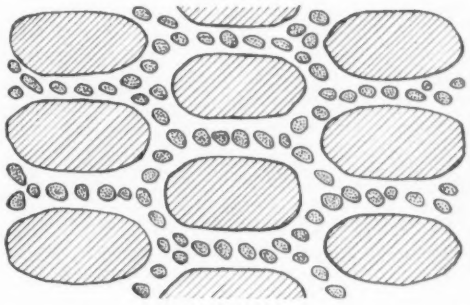


FIG. 2. SUBMICROSCOPIC, MICELLAR STRUCTURE OF CELLULOSE IN WALLS OF NATURAL FIBERS, AS PROPOSED BY C. NÄGELI (1877).

to propose the structure shown in Fig. 2. The introduction of a theory of crystalline structure here was, no doubt, suggested by the association between mineral crystals and optical anisotropy, known to physicists since the latter part of the seventeenth century. The idea, however, was a radical innovation, coolly received: the materials of plant life had been regarded as the epitome of the amorphous state. According to Nägeli's theory, rod-like crystals of cellulose, packed together as shown in Fig. 2, compose the fibrils which in turn compose a fiber. The axes of these crystals, or "micelles" as they were named by Nägeli, were supposed to be parallel to the fibril axis.

Micelles are beyond the limits of visual microscopy. Their existence was inferred on the basis of physical theory, and not directly observed. Later work confirmed the idea that cellulose is crystalline in some form. But, while birefringence can be examined by accurate methods, it was many years before Ambronn[3] initiated an analysis of the anisotropy to which the double-refracting effect is due. He found that the difference between the ordinary and extraordinary refractive indices does not have a constant value, as is the case with mineral crystals, but depends on the liquid in which the fiber is immersed. This be-

[3] H. Ambronn, *Kolloidzschr.*, 6: 222, 1910.

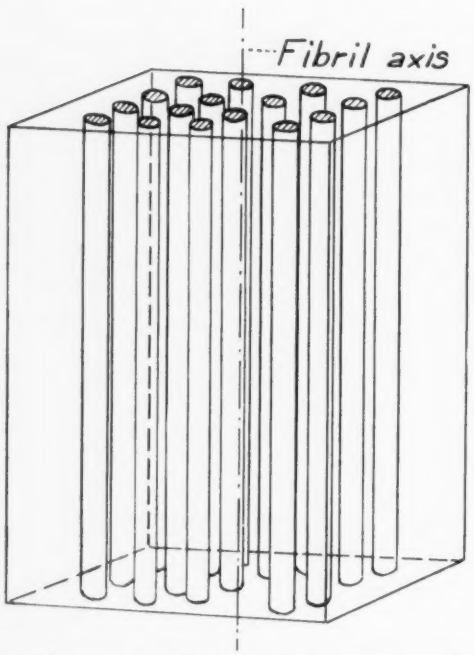


FIG. 3. RODLET MIXED SYSTEM. VOID SPACE (PORES) SURROUNDING THE CYLINDRICAL RODLETS IS PENETRABLE BY LIQUIDS HAVING DIFFERENT REFRACTIVE INDICES.

havior suggested that the fiber wall is porous, permitting the imbibition of liquid, which forms with the cellulose a "mixed system." Shortly after Ambronn's discovery, Wiener, an optical specialist, developed a complete mathematical theory of mixed systems.[4] This theory confirmed the porosity hypothesis by showing that birefringence results if the propagating field contains parallel rodlets of material having a refractive index different from that of the surrounding medium and a diameter smaller than the wave-length of the incident light. In Fig. 3 is shown a section of the idealized fiber wall which served as the mixed system analyzed by Wiener. In the present application, the rodlets are to be regarded as continuous masses of cellulose corresponding to Nägeli's micelles. In accordance with this explanation, when there is no difference between the indices of the two components of the mixed system the birefringence disappears, since the system becomes homogeneous. As a matter of fact, Frey[5] much later reported an experiment in which the cellulosic fiber itself was made to disappear when observed under a microscope, by employing penetrating liquids having appropriate refractive indices.

The rodlet birefringence discovered by Ambronn is, however, a second-order effect. In cellulose this effect is obscured by the more pronounced double refraction which arises from the intrinsic anisotropy of the cellulosic rodlets. Thus, while Ambronn and Wiener's work demonstrated quite conclusively that native cellulose has a structure of pores and rodlets along the lines of Nägeli's micelles theory, it did not invalidate the latter's assumption that the micelles are crystalline. It is not to be inferred that the micelle is now regarded as a single straight rodlet extending continuously through the fiber, as Fig. 3 might suggest. The structure shown here is a simplification of what modern theory holds to be the true structure.

To get a better idea of the real fine structure necessitates a study of the interior of the rodlike micelle. To this study the method of x-ray diffraction

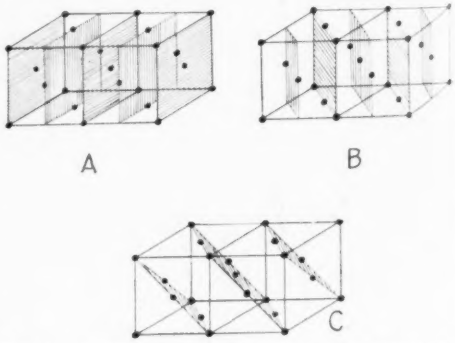


FIG. 4. SYSTEMS OF PARALLEL PLANES THROUGH A FACE-CENTERED CUBIC LATTICE.

[4] See footnote 2.

[5] A. Frey, *Kolloidchem. Beihefte*, 23: 40, 1927.

has been applied. It has been shown, as earlier theory had predicted, that there exist in the cellulosic mass submicroscopic crystallites, *i.e.*, regular lattice arrangements of atoms and molecules.

II. Crystal Analysis by X-rays

The atoms regularly disposed in a crystal lattice define a large number of planes with various orientations in the crystal. In Fig. 4 some of the principal layers of atoms are indicated for one type of structure, namely, a cubic lattice. When x-rays fall upon such a crystal lattice they are scattered in all directions by each of the atoms in the various planes. However, interference takes place and causes the diffracted rays to have only the directions given by mirror reflection of the incident rays from the various planes of the lattice. In accordance with the Bragg law, well known to physical scientists, these directions are functions of the wave-lengths of the incident rays and the distances between the layers of atoms in the lattice.

Let us suppose that a beam of x-rays is passed through a thin single crystal of calcite and falls on a photographic plate to form a so-called Laue pattern. There would be obtained on the plate an array of distinct spots such as is shown in Fig. 5. Each of the Laue spots (those outside the large central spot) is a diffraction maximum resulting from a particular set of planes in the crystal. From a geometric analysis of a Laue photograph much information about the type of the crystal and some idea of interplanar dimensions can be gained.

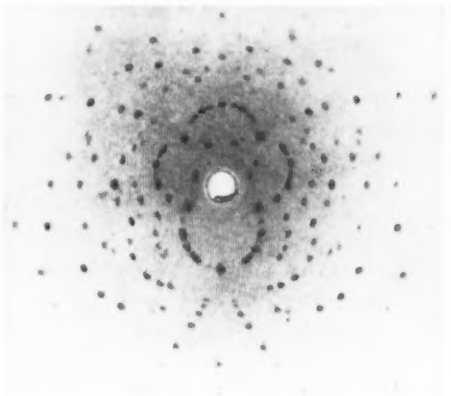


FIG. 5. LAUE PHOTOGRAPH OF CALCITE (CALCIUM CARBONATE). THE WHITE SPOT MARKS THE POSITION OF THE UNDIFFRACTED PRIMARY BEAM. (FROM ASTBURY, "FUNDAMENTALS OF FIBRE STRUCTURE.")

The crystal we have been considering could very well have been a thin square, *i.e.*, one having its length and width about equal and 5 or 10 times the thickness. Suppose a crystal thousands of times longer than it is wide and thick were chosen. Such a single crystal is supplied by the silicate, asbestos. If an x-ray pattern of such a single, fiber crystal could be obtained with a band of wave-lengths it would be found that it consisted of an array of spots of the type shown in Fig. 5. It is possible to obtain another type of pattern, however, if, instead of a single asbestos fiber, a bundle of such fibers was used with x-rays of a single wave-length. In this way the photograph in Fig. 6 was obtained. The pattern is symmetrical

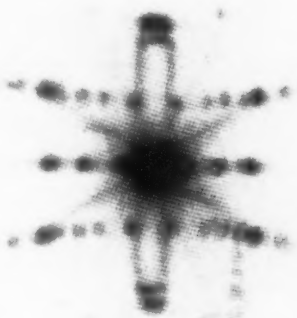


FIG. 6. X-RAY FIBER-BUNDLE PHOTOGRAPHS OF ASBESTOS. (FROM ASTBURY, "FUNDAMENTALS OF FIBRE STRUCTURE.")

about a vertical line corresponding to the vertical axis of the fiber bundle. The spots all lie on hyperbolae whose common axis is parallel to the longitudinal axis of the long crystals. This axis is the only crystallographic direction which has common parallelism among all the fibers. The other crystal axes are disposed at random. The orientation in three orthogonal directions which existed in the first calcite crystal has been degraded to orientation along only one line. The x-ray pattern reflects this condition in the repetition of spots along the hyperbolae. Again the directions in which the x-rays have been reflected can be deduced, and, applying the Bragg law, the distances at which the atomic pattern is repeated in directions parallel and transverse to the fiber axes can be calculated.

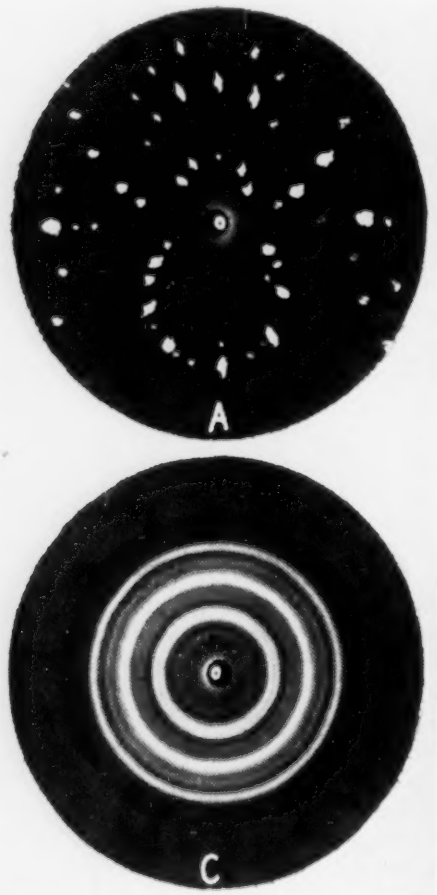


FIG. 7. EFFECT OF CRYSTAL SIZE ON X-RAY DIAGRAM OF SUCROSE. (A) CRYSTAL 1 MM. THICK; (C) PULVERIZED TO PARTICLES 0.001 MM. THICK. (COURTESY OF W. A. SISSON.)

This last remaining degree of orientation can be destroyed by pulverizing a crystal into minute grains. If x-rays are passed through the resultant powder a Debye-Scherrer pattern is obtained, such as that shown at the bottom of Fig. 7. This figure represents the pattern of pulverized sucrose, showing the concentric rings which characterize a powder diagram. The orientation of the granular crystals is now entirely random, so that no direction perpendicular to the incident x-ray beam is distinctive. The spots which appeared on the diagram of a single crystal of sucrose, shown at the top of Fig. 7, have spread out into circles about the center. The presence of these rings in an x-ray diagram indicates that the atoms or molecules composing the structural units are arranged on a crystal lattice, but that these units themselves are not oriented.

The relations between the structure of the sample and the x-ray pattern, which have been noted here for materials whose crystallinity is indubitable, are important in the interpretation of the x-ray diagrams of cellulose. This idea was employed as far back as 1913 by Nishikawa, a Japanese who obtained the first x-ray diagrams of a fiber. He noticed that there was a similarity between the symmetrical pattern of asbestos fibers and the patterns of some cellulosic materials. Though the latter patterns were not very clear, he concluded that cellulose must contain some kind of elementary crystals.

III. X-RAY STUDIES OF CELLULOSIC FIBERS

An x-ray diagram of native cellulose,

the sample used being a bundle of mature cotton fibers, appears in Fig. 8. It is immediately apparent from the presence of the rings in the diagram that there are crystallites in the structure of this unstretched fiber. Further analysis leads to the conclusion that these are crystallites of cellulose. The extent to which the rings are concentrated in arcs indicates some degree of parallel orientation of the needle-like, submicroscopic crystals which produced the x-ray pattern. On measuring the angular width of the x-ray arcs (57 degrees), Sisson[6] found that it was equal to the average divergence between the spiral fibrils, as indicated in Fig. 1. The conclusion is that the cellulose crystallites are packed in the fibril with their axes parallel to the fibril-axis, so that the crystallites run spirally around the fiber instead of straight along it.

When a cotton fiber is stretched are the fibrils stretched proportionately, or does the spiral simply become steeper, so that the fibrils and crystalline micelles become more nearly parallel to the fiber axis? That this latter takes place is deduced from examination of the x-ray diagram of stretched cotton fibers,[7] such as that shown in Fig. 9B. The cellulose of the fibers here has been partially modified by treatment with sodium hydroxide (mercerization). In this photograph the arcs have shrunk further to become more nearly spots, and other short arcs have appeared. That is, the diagram is tending toward the spot-type produced by a bundle of asbestos fibers, which we saw in Fig. 6.

Turning now from cotton to another native cellulosic fiber, ramie, a still better x-ray diagram, Fig. 10, is obtained. In the ramie fiber the fibrillar spiralling

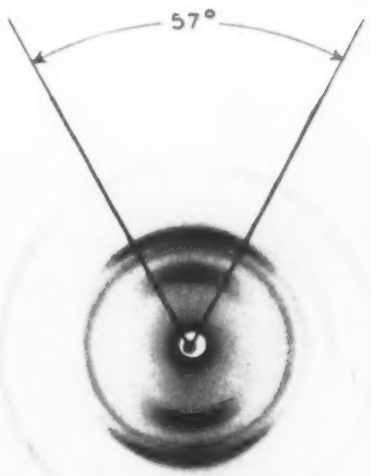


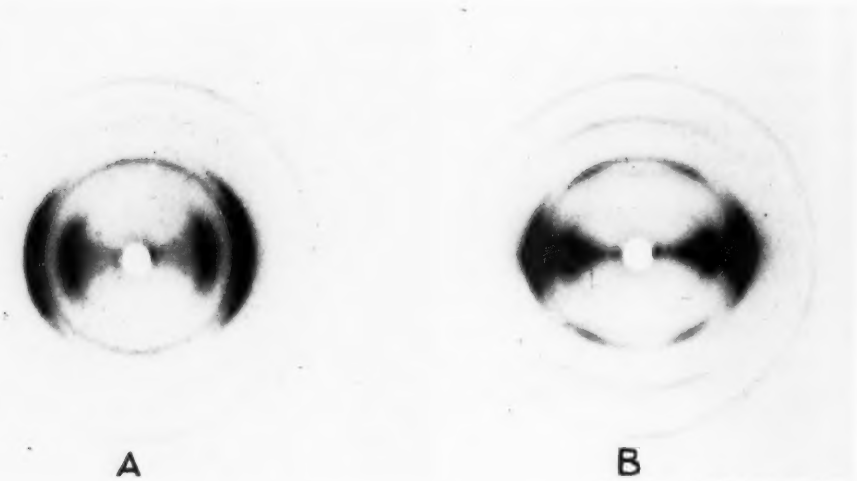
FIG. 8. X-RAY FIBER DIAGRAM OF UNSTRETCHED MATURE COTTON. (COURTESY OF W. A. SISSON.)

is negligible, so that the longitudinal axes of the crystallites should be parallel to each other and to the axis of the bundle. These expectations are confirmed by this pattern. The circles in the cotton pattern have disappeared, and the arcs have shrunk down to oval-shaped spots. From this type of spot, or "four-point" x-ray diagram of a cellulosic fiber, three sets of data are obtainable.

Firstly, the measurement of various distances between diffraction spots permits calculation of the separation between planes of atoms in the crystal lattice, as would be supposed from the Bragg law. Thus, it is possible to obtain the intervals at which the molecular, or multi-molecular, pattern repeats itself in all directions of the crystal. Measurements of this type reveal that the repeat-distance in the crystal of native cellulose, parallel to the fiber axis, is equal to twice the length of a glucose residue, as deduced from chemical data.

[6] W. A. Sisson, *Contrib. Boyce Thompson Inst.*, 9: 239, 1938. *Cf.* also D. R. Morey, *Textile Research*, 4: 491, 1934.

[7] W. T. Astbury, "Fundamentals of Fibre Structure," p. 88. Oxford University Press, 1933.

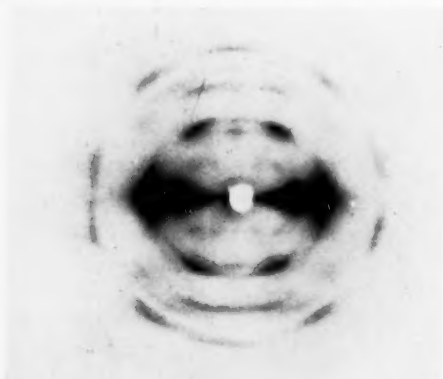


Courtesy of Earl E. Berkley.

FIG. 9. X-RAY FIBER DIAGRAMS OF A SINGLE SAMPLE OF COTTON: (A) FIBERS IN THE NATURAL UNSTRETCHED STATE; (B) SAME FIBERS AFTER BEING STRETCHED BY TENSION DURING MERCERIZING TREATMENT, AND THEN WASHED AND DRIED.

From this relation between the chemical unit and the crystallographic unit it has been concluded that the cellulose chain-molecules are arranged parallel to the axis of the native fibril.

Secondly, the intensity of the various diffraction spots provides a means for arriving at the number and kind of atoms in each of the planes to which the spots are due. The intensities are evaluated either according to relative rank by visual observation, or according to registration in a photometer. The planes having the most atoms and the heaviest ones in general produce the most blackened spots. In cellulose these planes are those of the hexagonal pyranose rings, containing carbon and oxygen, so that the x-ray investigators have been able to orient these rings in the crystal lattice. Studies on simple carbohydrates indicate that these rings are quite flat.[8]



Courtesy of Earl E. Berkley.

FIG. 10. X-RAY FIBER DIAGRAM OF RAMIE, A NATURAL CELLULOSE FIBER.

Finally, the width or sharpness of the diffraction spots gives an indication of the size of the crystallites from which the x-ray diagram arises. The relation between the width of the spots and size of the crystallites is inverse. It is evident that if the breakdown of a large single crystal into numerous crystallites has any significance, it will result in the reflections from the planes becoming less cooperative. The resultant spots on the photographic plate will be less confined and distinct. It is noticeable in Fig. 10 that the spots lying along the horizontal axis, or equator, near the center are

[8] Cox, Goodwin and Wagstaff, *Jour. Chem. Soc.*, 1495, 1935.

broader than those lying near the vertical axis, to which the fiber axis is parallel. The broadness of the equatorial spots is taken to indicate that there are fewer planes or layers of atoms parallel to the fiber axis than there are planes transverse to this axis. This condition, in turn, means that the tiny crystallites of which the fibrils are composed must be rodlike, *i.e.*, much longer than they are thick, and furthermore must lie with their lengths along the fiber axis.

The first adaptation of x-ray diffraction data on cellulose to the determination of the dimensions and character of the crystal unit was announced by Polanyi[9] in 1921. Measurements of this type, and their interpretation in the light of chemical evidence, have since been refined. The latest revision of Meyer and Mark's model of the cellulose crystal unit appears in Fig. 11.[10] Associated with the cellulose unit are two cellobiose residues, each containing two of the pyranose rings of glucose. These rings are connected along the b-axis by primary valence bonds to form the long-chain molecules. The a- and c-axes are transverse to the fibril axis, though not quite perpendicular to each other.

A quantitative interpretation has been made of the relation between spot- and crystal-size by Hengstenberg and Mark and others[11] to calculate the dimensions of the colloidal crystallites or micelles in a cellulose fiber. Their conclusion was that the micelle is at least 600 Å. long and about 50 Å. broad.[12]

The x-ray data, as they concern micellar size, are in agreement with the results of the optical studies. After reviewing all the data, Seifriz[13] proposed

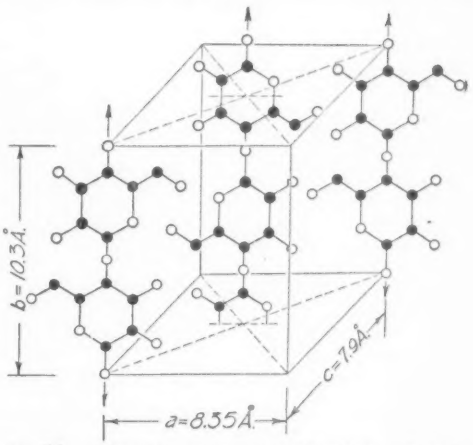


FIG. 11. CRYSTAL UNIT OF CELLULOSE, AS REVISED BY MEYER. BLACK CIRCLES REPRESENT CARBON ATOMS; HOLLOW CIRCLES OXYGEN ATOMS. THE LIGHT HYDROGEN ATOMS ARE OMITTED.

for native cellulose the structure shown in Fig. 12, in which the crystallites are packed like bricks in a wall. The cut-away section shows the atoms of the cellulose molecules composing the bricks. This neat structure is a revival of Nägeli's pattern. It was not intended to be complete, and accurate in every detail, but to represent the main features of the submicroscopic system of cellulose. Certain features are not consistent with more recent physico-chemical observations. For instance, values for the coefficient of viscosity of cellulose dispersions indicate that the average molecule of native cotton cellulose is 10,000 Å. long, while use of the ultracentrifuge has yielded lengths of around 18,000 Å. Obviously, molecules of these lengths could not be restricted to a single block 600 Å. long, without being folded back on themselves.

Concerning the relation between aggregates on the scale of the micelles which have been discussed, and the fibrils of cellulosic fibers, various theories have been advanced during the past fifty years. In general, these theories

[9] M. Polanyi, *Naturwissenschaften*, 9: 288, 1921.

[10] Meyer and Misch, *Helv. Chim. Acta*, 20: 232, 1937.

[11] H. Mark, *Jour. Phys. Chem.*, 44: 764, 1940.

[12] 1 Å. = 1 Ångstrom unit = 10^{-8} centimeters.

[13] William Seifriz, *Amer. Naturalist*, 63: 410, 1929.

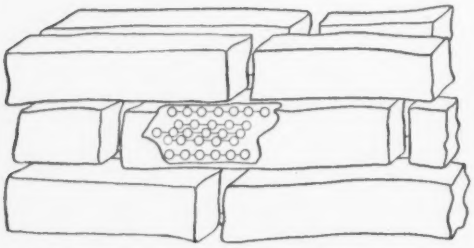


FIG. 12. SHARPLY-DEFINED CRYSTALLINE MICELLES IN NATIVE CELLULOSE, AS PROPOSED BY WILLIAM SEIFRIZ IN 1929.

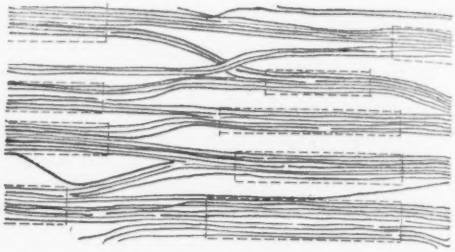


FIG. 13. NETWORK STRUCTURE OF ORIENTED CELLULOSE. MICELLES ARE INDICATED BY DOTTED LINES; EXCLUDED REGIONS ARE POROUS.

involve the existence of intermediate units which, bound together in a ribbon-like structure, compose the fibrils. Wiesner first advanced the idea of such particles, which he termed "dermatosomes." On treating fibers with phosphoric acid, Ritter observed under the microscope fibrillar sections which he termed "fusiform bodies.[14] During recent years evidence has been introduced by Wanda Farr and her associates[15] indicating that the basic unit of native cellulose is an ellipsoidal particle about 15,000 Å. long and 11,000 Å. across, somewhat larger than the particles proposed earlier. Whether these particles have objective existence as self-contained, basic units, or are indefinite, artificial aggregates of micelles is an unsettled question.

[14] G. J. Ritter, *Ind. Eng. Chem.*, 21: 289, 1929.

[15] Farr and Eckerson, *Contrib. Boyce Thompson Inst.*, 6: 189, 1934. W. K. Farr, *Jour. Applied Physics*, 8: 228, 1937.

The concept of the fine structure of native cellulose most widely accepted at present is illustrated in Fig. 13. Here regions of micelles, depicted as somewhat vaguely defined, crystalline bodies, are separated by regions of porous or amorphous matter. The long-chain molecules of cellulose pass from one of these regions to another, somewhat at random, but always more or less parallel to the fiber axis. In the micelles the chains are well oriented;[16] in fact, that supposedly is what makes the micelles what they are—crystallites. In manufactured cellulosic filaments, this orientation is generally lacking. In general, also, stretching improves the orientation in both the natural cellulosic fibers and the filaments manufactured from cellulose.

[16] O. Kratky, *Angewandte Chemie*, 53: 153, 1940; translated by Julian F. Smith in Hooker Scientific Library Cellulose Series.

ADJUSTABILITY OF THE LIFE PROCESS TO INJURIOUS AGENTS[1]

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LIKELY the most constant characteristic of the life process is its inconstancy, not its inconsistency. What may appear as inconsistency in it is due to our inability to understand and appreciate the most fundamental attribute of life—change. The natural tendency of a mind is to classify, to card-index individuals, processes which take place in them, even situations and circumstances, for this is the easy way. It has in it an element of permanency, it tends to be static: again, it is the easy way. Through such a card-indexing we may put down and fix even a thought to come back to it at will and find it where we placed it. The life process has nothing of fixity to it: it is indicated by change, genetic change, cellular change and the ever changing nature of the chemical constitution of life, constituting as it does morphology in an attempt at adaptation and balance. Through change a balance must be achieved in the life process to enable it to relate itself and move without friction as function. A failure of cell adaptation to a changing normal and frequently to an abnormal environment ultimately results in such a degree of maladjustment that useful life becomes impossible. This life goes by "fits and starts," it lacks a smoothness, translated as purposefulness, and its end is death. It therefore becomes the function of the "biologically minded physician" to realize and attempt to understand the significance of physical and chemical change in the organism and in turn institute those measures which will further the processes of adaptation. Such natural processes operating over periods of days, and also over geological periods, may result in changes in form significant for transitory or permanent adaptation. Even ephemeral states of a functional order, such as fever, an increase in the number and activity of wandering cells, may be of a purpose tending towards tissue adjustments.

Hippocrates realized the significance of change in surface form. The narrow-chested, pale and blonde individual with "winged scapulae" to him in his wisdom was a type or form of individual in which tuberculosis was apt to develop. These observations dealt with form and changes in form as they departed in form from that which to him was normal and related. Later than this the anatomists, some of whom were to be later designated pathologists, were permitted to observe and study organs within the dead and unrelated body so they might ascertain once again in the gross what were those changes in this or that organ designated diseased states which unrelated the individual to his environment, which prevented adaptation and which resulted in death. Centuries later than this, when the use of the microscope became available for the hands and through the mind of Virchow and Cohnheim, more particulate observations were made possible. Tissues and organs were found to be made up of units designated cells, and the cell became the structure to consider as influenced by the normal and the abnor-

[1] The last in a series of three articles on "Tissue Susceptibility and Resistance" contributed by the author.

mal process. As a result of Virchow's great work we were enabled to penetrate into the hitherto unseen; from the surface observations of Hippocrates, the later gross observations of the anatomists and pathologists as to organ change expressing faulty adaptation, to a new realm of cell change; cell change in terms of microscopically demonstrable change. Until recently we have had to remain in this domain of understanding, of incomplete understanding of the processes of cell life translated through cell form.

As a result of the studies of the microscopic anatomists we have been given what they consider accurate, measurable information concerning normal cells of various types. Such normal cells are not infrequently seen as fixed entities lacking the elasticity necessary for change and adaptation under the strain of normal life, and especially when that life becomes so abnormal that change of a major order must take place in order for such an emergency in life to be checked and adjusted. Such adjustments are made even in the normal, not through gross morphological change, but by a chemical and physicochemical order of change which in the abnormal may assume such proportions as to express the aggregate of chemical change as altered morphology. With such a conception it becomes unwise to assume fixity in cell form as representing a given normal and that any departure in form from this hypothecated normal a manifestation of disease, a cellular adventure towards dissolution and death. On the contrary the chemistry of life within the cell must change quantitatively and in its rate and degree of completion, and the form of cells may shift in normal life through these changes, and do change in abnormal life, not for death, but for adapted life with fair function and one which, even though it be adapted at a lower level of functional effectiveness, has acquired through cell change and the chemical changes within the cell an element of resistance against further change of a degenerative nature.

Such thoughts make it difficult for one to determine just what disease consists in. Just where does cell change for adaptation and life cease and cell change for death commence? Liver cells and kidney cells of normal adult animals have been shown to be highly susceptible to an influence exerted by substances such as uranium nitrate, chloroform and ether. At such age periods this susceptibility which must be of a chemical order as affinity enables these cells to change under such influences. We speak of these alterations as disease because they tend to unrelate an adapted organism. Cells in the same locations in these organs in puppies and young adult animals fail to show such changes. They have a chemical constitution which prevents or lessens such changes, and we are satisfied to label such cells normal cells because of their resistance. On the contrary the same type of cell in the same location may so react to injury designated disease that it not only changes its form and chemical constitution but associated with the change becomes resistant and maintains life when it is subjected to these injurious agencies. These are entirely different cells from those we have labeled normal. Should such cells be called diseased cells, or should we see them from a broader biological point of view, a more elastic and changing point of view, as constituting a tissue which has so participated in a stream of life induced by a chemical affording a difficult chemical environment, and which have survived through adaptation to this environment and thereby make their contribution, not only to organ survival, but through such a localized tissue resistance, to survival of the organism as a whole. This approach to tissue changes and to chemical

changes within a living organism as a whole should give us pause in our eagerness to employ artificial agents in order to hasten the bringing back of the organism to what we hypothecate is the normal for it in a given situation. Adaptation which leads to stabilization finds "success in the silences" and is often not of a rapid order of development. The normal for any living organism is not a fixed and static normal, but an ever changing normal. Cell changes of designated degenerative order and the chemical background for them may be considered as a part of a process which may lead to chemical shifts and morphological alterations resulting in life with acquired protection.

To this point in our discussion we have spoken of form and changing form, and through such a consideration have advanced from a concept of surface form to normal and pathological organ form in the gross, and finally to microscopic cell form. The discussion has not concerned itself with those chemical configurations within cells responsible for their change in form and in chemical affinity. The time has now come for the biological chemist and the physical chemist and that composite of the two, the pharmacologist, to advance through the spade work of the anatomist and pathologist, to within the cell and through the fluid which bathes it in such an intimate fashion, for an understanding of those chemical processes of a normal order, of a pathologically destructive order and lastly of an order which permits adaptation with sufficient function for survival.

In addition to such considerations of cell change and inferred chemical change which permits shifts in life with or without resistance, there may occur in an organ such as the kidney changes of a grosser microscopic nature which appear to be structural expressions on the part of such an organ to survive sectionally as a functional entity. In a previous discussion[2,3] of the kidney injury which develops from the use of uranium nitrate it was pointed out that in one form of adjustment as a repair process, the proximal convoluted segment of the tubule became relined by a very flattened and atypical type of cell. In some locations these cells or syncytial structures are flattened to a degree as to take on the appearance of an endothelial relining rather than one of an epithelial character. Such changes require several months for their development. This alteration can not be looked upon as a degeneration. It is a product of repair with the formation of a new structure with normal staining reactions. At the same time such changes are developing in the epithelial tissue of the tubule the glomeruli undergo gradual changes, secondary to the acute injury, which results through the formation of connective tissue in a gradual and uneven obliteration of the glomerular capillaries. Months before such obliteration becomes complete it is usual to find glomeruli which are no longer capillary structures, but canalized structures. The number of such vascular canals lined by endothelium and containing blood is variable, depending upon the extent of the connective tissue obliteration to which the glomeruli have been subjected. When such kidneys are injected with a colored mass through the renal artery prior to the animals' death the injection mass is found to pass through such glomerular canals and localize itself in terms of quantity in the second set of capillaries in the region of the proximal convolution which is now lined as a result of repair by extremely flattened cells. Blood, therefore, passing through such canalized glomeruli, is so placed that it may be acted on or

[2] Wm. deB. MacNider, *Jour. Exp. Med.*, 49: 387, 1929.

[3] *Idem, Jour. Exp. Med.*, 49: 411, 1929.

exert its influence through such very atypical tubules of a repaired and surviving order. Not infrequently the broad lumen of such tubules lined by extremely flattened cells shows an indentation or commencing invagination of its wall through capillary pressure from without, inward. It is interesting to conjecture whether or not such a gross alteration in renal architecture is not leading to the formation of a modified type of glomerulus with in part a maintenance of glomerular function by filtration through an atypical segment of the tubule below the now inactive glomerulus. Embryologically it should be recalled that glomerular formation develops by just this type of process through capillaries invaginating a tubular segment. An ontogenetic process may exert its influence in organ survival when such organs are subjected to slow but progressive injury. In other areas of such injected pathological kidneys the colored injection mass may be followed through the medulla of the kidney, into the cortex and become localized in capillaries around tubules repaired with flattened cells in areas in which complete glomerular capillary obliteration has taken place. Such glomeruli are no longer canalized. These structures have become obliterated by fibrous tissue formation and an associated hyalinization of this tissue. An aglomerular structure has been formed through injury with the atypically repaired and resistant part of the nephron receiving blood for purposes of nourishment and possibly for function by an ingrowth of capillaries from below. The composite repair process in this instance has resulted in the formation of a structure phylogenetically of a normal order for the aglomerular fishes.[4]

These examples of changes in the form of structures as a whole (the renal nephron) as well as changes in cell form, and finally in the changes of the chemistry of such cells impress one with the extent to which tissue changes may go in order for cell function and organ function, modified as they may be, to persist in an adapted state and so effect the survival of the organism as a whole.

From this discussion the significance of change, of change as a characteristic and function of life is apparent. The continuance of life depends upon the elasticity and adaptability of its nature determined by chemical and physicochemical forces of an order of which we are in large measure ignorant other than the dominating genetic factor. Such an admission offers a broad field for investigation into the life span of any species of animal or plant in which the element of change is the outstanding characteristic of life as normal adapted life, as maladjusted abnormal life, and as life as it passes from birth through successive modifications, finally terminating with death in senility.

[4] *Idem. Proc. Soc. Exp. Biol. and Med.*, 31: 293, 1933.

THE YOUNG NATURALISTS' SOCIETY

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I. In the Beginning

Two fifteen-year old boys sat together at one of the old-fashioned desks of the Jefferson Public School at 10th Street and Hennepin Avenue, Minneapolis, during the school year of 1873–74. Tom lived in town, but Clarence walked every morning from an outlying farm and was often tardy. The boys quickly became intimate, for they had many interests in common and Clarence had no other playmates. Of course they must not whisper, but there was so much to tell that Clarence fell into the habit of sketching on his slate a pictorial record of his activities since yesterday—milking the cow in a swarm of flies, gathering potato-bugs or husking corn. The teacher (who evidently had no sense of humor and little of any other sort), noting something unusual, one morning called Clarence to his desk with the slate. On seeing the pictures, which were both realistic and fantastic, he gave the boy a severe whipping. Clarence returned to his desk with a smarting palm and a smiling face and refilled the slate with caricatures of the teacher.

The following summer these boys with two other schoolmates camped on an island in Lake Minnetonka, and here the interest in birds and all other wild life which hitherto had captivated their childish minds now became a ruling passion which endured and shaped the whole subsequent courses of their lives. This camp was probably the seed-bed within which the Young Naturalists' Society germinated. Tom, with rare pertinacity, clung to his first love, the birds; but Clarence's interests, apparently from the dawn of his interest in anything, were spread over the whole face of nature.

In September of that year, 1874, these boys entered the Minneapolis high school, where during the three-year course and for some time thereafter their exploits as "Young Naturalists" were so original and productive as to merit description. A record of the activities of these young pioneers written week by week with their own hands has fortunately been preserved, and these yellowed pages contain something of historical interest and much of inspirational value for us of a later generation.

Through the kindness of Dr. Thomas S. Roberts, director of the Minnesota Museum of Natural History in Minneapolis, these papers have recently come into my hands. They are of interest for two reasons: first, they document a critical period in the history of science in the upper Mississippi Valley, embracing the years 1875 to 1878; second, they give illuminating glimpses into the intimate lives, habits and mental furnishings of a small group of exceptional children whose spontaneous interest in natural history came to expression in the formal sessions of their society. Here we see the quickening and operation of scientific interest in the minds of sixteen-year old boys and remarkable industry and originality in the cultivation of these interests. The cultural background and historical development of their community in 1875 have been outlined in a previous article.[1] Extracts from these documents are presented with some commentary. Two of the three promoters of this

[1] C. Judson Herrick. Scientific Pioneering in the Middle West. Scientific Monthly, Vol. I, pp. 49–56.

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society are now living in Minneapolis and they have given me interesting details which supplement the written record.

II. Organization and Procedure of the Society

On the 12th of February, 1875, seven boys organized the "Young Naturalists' Society," whose records show continuous activity until November 18, 1878. These boys were members of the first-year class of the Minneapolis high school. There were some later additions and some withdrawals, but the number of members remained about the same and four or five of them were active throughout the life of the society. These included Thomas S. Roberts, Clarence L. Herrick, Robert S. Williams and Frank P. Clough, son of the city engineer at the time of threatened disaster to the Falls of St. Anthony (1869 to 1876). Regarding the inception of the society, Dr. Roberts writes me:

> The nucleus consisted of Clarence, Robert S. Williams and myself. I was the promoter and furnished the place of meeting—my bedroom. This was on the second floor, reached by a side entrance, through the diningroom and up a back stairs. It was heated by a little drum stove and provided with storage arrangement for specimens, etc. Here we assembled and sat around in earnest conclave, for we were a serious bunch. Our youthful friends of different minds were wont to poke fun at us by sending us bogus specimens from time to time. But we went gravely on our way. Clarence did the best work.

It is an important point, here reiterated, that neither the society nor any of its members had any significant contacts at school or elsewhere which might encourage or guide their activities before the end of September, 1875. During the following two school years Mr. Roberts continued in the high school, graduating from the three-year course in 1877. But Clarence left the high school to enter the preparatory department of the university. The official records of the University of Minnesota show an application for admission by his father dated Sept. 28, 1875, "for 6 years." Beginning in the autumn of 1875, he attended four years and two quarters, graduating with B.S. degree in June, 1880, thus completing the six-year course in less than five years. His competence as a naturalist very soon was recognized, for within less than a year of matriculation he was appointed assistant to Professor N. H. Winchell, director of the Geological and Natural History Survey, and his extracurricular activities in the Survey probably were of greater educational value to him than any of the regular courses. This influence was perhaps similar to the help which the young G. H. Parker received from the Academy of Natural Sciences in Philadelphia, as recorded in an autobiographical note.[2]

Robert Williams also came under Professor Winchell's influence at some time during the active life of the society. He did not graduate from high school and probably entered the preparatory department of the university, for in a recent letter to me he writes:

> I first took up an interest in birds and began making skins and trying to mount them along with other boys in the neighborhood. I paid little attention to plants until attending the Minnesota University for a short time. I had to pass an examination on local plants and make a collection of fifty specimens. This I did and received 100% on it from Prof. Winchell.

It is obvious that from the date of Clarence's matriculation at the university in the autumn of 1875 this connection with an organized scientific program was a significant help to the society and all its members; yet this certainly was not the source of its initial motivation. In origin it was parthenogenetic, not sired by any outside person or influence; and its form and procedure were not sensibly changed during the later years when Clarence was Professor Winchell's assistant.

[2] G. H. Parker. *Frontiers*, Philadelphia, January, 1937.

That they had access to books is evident, and at first these were probably drawn largely from the public Athanaeum library, later no doubt from the university library. That they used the available literature to good purpose will appear shortly. For other equipment they were dependent almost entirely upon their own resources, for there was little money except from the small monthly dues and fines.

Among the spoils of war brought home by Clarence's father from his Civil War campaigns was an old Springfield army rifle which had done heavy duty at the front. Heavy duty is right, for none but a husky man with good teeth could manage this clumsy piece of ordnance. The strong paper cartridge containing the leaden bullet and a charge of black powder was torn by the teeth, inserted in the muzzle and then rammed home, to be discharged by a percussion cap. The recoil was terrific and the execution out in front was appalling if the rifle-ball met its target. This ancient weapon, with the rifling of the barrel reamed out so as to transform it into a muzzle-loading shotgun, was Clarence's only equipment in the early days of his collection of birds and mammals. With a light charge of small birdshot and due attention to the erratic disposition of sights and scatter, he usually contrived to bring down the smallest bird in perfect condition. But not always, and I well remember his rage when a rare specimen fell as a mangled wreckage of blood and feathers.

During Clarence's high-school days his father out of his poverty bought him an eight-dollar microscope. There were no such refinements as coarse and fine adjustment, merely a tube sliding in a sleeve for focussing. But the lenses were good, and with that crude instrument he explored the fauna of ponds and ditches so diligently and productively that, of the three short papers prepared for publication before he entered the freshman class at the university, one was entitled, "A New Cyclops." These papers were published in 1877, the others being, "Ornithological Notes" and "The Trenton Limestone at Minneapolis."[3] The minutes of the Young Naturalists' Society show that these papers were prepared for the society and read at regular sessions; and the range of subjects which they embrace is typical of the catholicity of interests cultivated by these youngsters.

Meetings of the society were held in the evening, at first weekly and later biweekly throughout the year, including the summer months. Mr. Roberts was the first president, and he was reelected for the following term also. In his "Report of the Secretary of Young Naturalists' Society" for the six months ending January 14th, 1878, he writes:

> Since March 12, 1875, one hundred and nine (109) regular meetings have been held, all of them with the exception of one or two in this room. Twenty-six (26) regular meetings were held during the past year. . . . March 5th the regular monthly tax which had been 10c was reduced to 5c which it still remains. . . . There are in the society's possession forty-four (44) original papers written by its members, and eight (8) reports. The papers were mostly read during the year 1875 and the first part of 1876. Some if not all of these would probably bear rereading and general criticism.

One of the primary objectives of the society was the preparation of accurate lists of the local fauna and flora. In Secretary Roberts' report at the end of the third year he writes:

> The ornithological list since it now numbers one hundred and ninty-four (194) out of a possible three hundred (300), does not increase very rapidly. Four (4) new species have been handed in during my term—vis.; the Blue-gray

[3] C. L. Herrick. "Ornithological Notes." Fifth Annual Report of the Geological and Natural History Survey of Minnesota (for 1876), St. Paul, 1877, pp. 230–237. "A New Cyclops." *Ibid.*, pp. 238–239. "The Trenton Limestone at Minneapolis." *Am. Nat.*, Vol. 11, pp. 247–248, 1877.

Gnatcatcher (*P. caerulea*), by R. S. Williams, and the Gray Snipe (*M. griseus*), Ring-billed Gull (*L. delawarensis.*) and Lecontes Bunting (*C. lecontei*) by C. L. Herrick. Two of these are especially noteworthy; the Blue-gray Gnatcatcher on account of its occurrence so far north, it being essentially a southern species; and Leconte's Bunting, from its general rarity and meagre history. Several other new species have been taken but not yet entered upon the list.

More work has been done in Botany than in any other branch; at least the results are larger; but this is to be accounted for in great part by the field being new and large. The names of the plants identified were at first kept in the form of a wholly unclassified list. By the time a hundred and fifty (150) species, or only one summer's work had been thus entered it was found that the list was rapidly becoming unmanageable. . . . In the scattered condition of the list just at present I cannot say how many species have been identified but think the whole number closely approximates five hundred (500).

The list in Paleontology contains fifty (50) species the result with but two (2) exceptions of the work of Mr. Herrick. The Entomological list includes 31 species. But few additions have been made lately. The last is the Zoölogical or miscellaneous list which contains thirty-one (31) species, covering mammals, reptiles, and fishes. These in due time will find their proper places when lists in their respective departments are started.

These lists were never published, save for a list of birds[4] and a reference to a list of plants in Warren Upham's Flora of Minnesota.[5]

The constitution of the society has not been preserved, though its salient features are summarized in one of the Reports quoted beyond. It evidently received very serious consideration, for the minutes record repeated revisions. Officers were elected for a term of six months and comprised a president, vice-president, treasurer and secretary, besides standing committees on ornithology, entomology, botany, geology, conchology and physics. The usual order of business included a roll-call, reading of minutes and presentation of original papers and assigned readings, followed by general discussion. Formal debates are reported upon these, among other topics:

The state of the interior of the earth.

Which have the greatest influence upon agriculture—birds, insects or rodents?

Have birds and animals more than instinct?

Which has the greatest influence upon the form of a country—water in a flowing condition or all the other influences combined?

The relative importance of the natural sciences among the sciences.

The list of assigned readings as recorded in the minutes reveals some of the sources available to these boys and more about the range of their interests. The following are selected from a larger number:

Selections from Audubon; Marsh's "Man and Nature"; Geography and Evolution; Form and Life; The Stone Age; Frauenhofer's Lines; Vortex-atom Theory; Insectivorous Plants; The Flight of Birds; Cause of Earthquakes; The Great Auk; Influence of Habitat on Animals; Croll on "Climate and Time"; The Relation between Sunspots and the Price of Wheat; The Difference between Eastern and Western Birds; Theory of LaPlace—Creation; Rise and Progress of Modern Views as to the Antiquity and Origin of Man (A. R. Wallace); How Plants are Fertilized by Insects; Localization of the Functions of the Brain; Wild Mice and their Ways; Fertilization of Orchids; Transmission of Excitations in Sensory Nerves (Paul Bert); Theory of Tides; Song Birds of America; Obituary of Professor Henry; Intellect in Insects; Insect Wings; Structure and Affinities of Hummingbirds; Variation in Nest-building.

These topics have a modern ring in 1942, and this is what these high-school

[4] "Ornithological Notes" by C. L. Herrick in the Fifth Annual Report of the State Survey, already cited, include a list of 91 birds added to the collection of the University Museum, where they still are. Most of these were collected in the summer of 1876. There are annotations upon some of the rare or atypical specimens and their parasites.

[5] Warren Upham's "Catalogue of the Flora of Minnesota," published in the Annual Report of the Survey for 1883 (Minneapolis, 1884) has the following statement on page 10: "A list of about 500 species, observed chiefly in the vicinity of Minneapolis by the Young Naturalists' Club, was communicated by Mr. Thomas S. Roberts, by whom nearly all of these species were determined, others by Clarence L. Herrick, F. S. Griswold, and R. S. Williams."

boys were reading and thinking about more than sixty-five years ago.

The original papers were carefully written and filed in the Archives. Some were illustrated by drawings, specimens or experiments. These papers were not digests or reviews of literature; it was expected that each one of them should report original work of some sort. Lectures delivered extempore were apparently discouraged, for we read in the minutes of November 25, 1875, "Mr. Herrick was allowed to extemporize. Subject, The Cyclops." It is reported, however, that during the third year few original papers were written and there were seven unwritten addresses. Here are some of the titles taken from the minutes:

Essay by Clarence Herrick.

List of birds presented by Mr. Roberts. This entry appears frequently throughout the record; also lists of flowers.

List of insects presented by Mr. Herrick.

List of fossils by Mr. Herrick.

Essay on Our Winter Birds by Mr. Roberts.

The Balance of Nature by C. L. Herrick

Remarks upon a blackbird by the President (Mr. Herrick).

General discussion upon capillary attraction and cause of circulation of sap in plants.

Discussion about making a dredge.

Extemporaneous speech on some of the most noticeable animals in a bucket of water by Mr. Herrick.

Papers by Mr. Roberts on The Hummingbird, The Swallows, The Scarlet Tanager, The Least Bittern, The Nesting of Robins, Algae.

Papers by Mr. Williams on The House Wren, The Wax-wings, The Brant.

Entomostraca by Mr. Herrick.

Mimicry among Animals by Mr. Roberts.

III. The Records

The documents relating to the Society which have been preserved are as follows:

1. Minutes as written by the secretaries from March 5, 1875, to November 18, 1878.

2. Mr. Roberts' first president's report, July, 1875.

3. Eight semiannual reports by the secretaries and treasurers at the close of their terms.

4. Six reports for the term ending December 31, 1876, by the committees on Entomology, Ornithology, Botany, Geology and Mineralogy, Conchology and Physics.

5. An ornithological report addressed to Dr. P. L. Hatch, State Ornithologist, dated March, 1878, and recording observations made during 1877 by Thomas S. Roberts, Robert S. Williams and Clarence L. Herrick.

6. The manuscripts of five original papers by Frank Ham, eight by C. L. Herrick, two by Robert S. Williams and one by T. S. Roberts. These sixteen papers are all that have survived from the forty-four reported as on file in the archives of the society in January, 1878.

7. Many letters by members of the society or relating to it.

The documents here listed are now filed in the library of the State Museum of Natural History, Minneapolis, Minn. Many of the specimens collected by the society are preserved in the same Museum.

These documents will now be reviewed and annotated. In the quotations from them which follow the original form, punctuation and spelling of words are scrupulously followed. Most of these boys were weak in spelling, and in the case of at least one of them (Herrick) this disability persisted as long as he lived. The present writer is not inclined to be very censorious about this; for to this day, despite the reading of many thousands of pages of proof over a period of fifty years, he still finds it necessary to keep a dictionary at his elbow—not for technical terms, but for the common words.

IV. Minutes of the Society

The original copy of the Minutes is a foolscap folio of 58 closely written pages. Most of the entries are neatly written in ink and some are in pencil. The first entry is undated and probably is of March 5, 1875, for the next entry is dated March 12 and the succeeding meetings follow at weekly intervals. The secretary's record of the meeting first reported is typical of those which follow.

"Reading by Mr. Scott, 'The Bladerwort.' Essay by Mr. Clough, 'Metamorphosis.' Reading by Mr. Williams, 'Spiders.' Essay by

Clarence Herrick. Remarks upon the fluctions in Bassets Creek. List of Birds presented by Mr. Roberts. List of Insects presented by Mr. Herrick.''

The program of June 12 of that year included a paper by Mr. Clough and ''a paper read by C. Herrick in place of reading as was assigned.'' Mr. Roberts handed in lists of birds and flowers.

At the first meeting of the second half-year, July 2, 1875, officers for the next term of six-months were elected: President, Mr. Roberts; Vicepresident, Mr. Williams; Secretary, Mr. Herrick; Treasurer, Mr. Clough. On July 9 the President reviewed the history of the society and the Treasurer's report showed receipts of $5.15 (dues $4.55, fines for absence or failure to meet assignments $.60), expenditures of $1.40, and cash on hand, $3.70. There is no record of an audit or comment on the apparent discrepancy in the cash account. An examination of the itemized Report separately filed reveals an error in subtraction.

On July 28, after a reading by Mr. Williams on ''Animalism in Plants,'' Mr. Roberts presented a paper on ''The Scarlet Tanager.'' It was then voted to purchase a case of drawers for the preservation of specimens. That the discussions were animated and often prolonged is indicated by the minutes of a meeting in December, 1875:

''Society called to order by the President. Minutes read and corrected. Parts assigned. The reading of Mr. Clough omitted as he was not prepared. Reading by Mr. Ham — Fleas & Bugs. Paper of a week ago read by Clarence Herrick. Notice of two amendments given by Mr. Herrick. Mr. Leon Lum admitted as member of society. All the members signed the constitution. List of several insects handed in by Mr. Ham. The name of one new bird presented by Mr. Roberts. Conversation on various topics. Moved and seconded to adjourn, lost. Conversation resumed. Moved and seconded to adjourn, lost. Descussion regarding Darwinism resumed. Move and seconded to adjourn, carried. Society adjourned.''

Officers for the next term of six months were elected Jan. 7, 1876: President, Mr. Herrick; Vicepresident, Mr. Williams; Secretary, Mr. Lum; Treasurer, Mr. Scott. Successive parts of the ''Inaugral Address'' of the newly elected president were read at meetings of Feb. 4, Feb. 11, and May 12. Mr. Herrick was reelected for a term of six months, July 1, 1876. The following is the complete record of the meeting of Feb. 11, 1876:

''Society called to order by the Pres. Roll call. Minutes of last meeting read and approved. Parts assigned. Literary exercises. Reading by Mr. Williams. sub. Vinegar Plant. Reading by Mr. Lum Sub. ''America the Old World.'' Reading by Mr. Roberts sub. ''The Rattlesnake.'' Moved and seconded that a committee be appointed to confer with Mr. Gillespie and see if the members of the society could visit the Government Works. Carried. Messrs. Clough and Roberts appointed. Moved and seconded that a committee be appointed to confer with Mr. Ham and exort him to be more regular in his attendance. Carried. Messrs. Scott and Williams appointed. Moved and seconded that those who were absent Jan. 28th be excused. Carried. General discussion. Presidents Inaugral contin. Moved and seconded to adjourn. Carried. —Leon Lum. Sec.''

At the next following meeting, of Feb. 18, we read: ''Report of committee appointed to call upon Mr. Ham called for. The committee reported that Mr. Ham gave as his reason for not coming that there were only 168 hours in the week so he had no time to come and if the society could make any more he would be happy to come. General discussion.'' Apparently the discussion did not yield a satisfactory resolution of Mr. Ham's problem, for his name does not appear in the minutes of any subsequent meetings.

The ''Government Works'' mentioned in the minutes of February 11, 1876, were of lively interest as the final chapter of a thrilling history of desperate struggle to save St. Anthony Falls from sudden and total destruction. This would mean the loss of the waterpower and the ruin of the city's chief industries.

St. Anthony Falls were discovered and named by Louis Hennepin in July, 1680. The next white man to publish a report of a visit was Jonathan Carver in 1766. Following the Louisiana Purchase (1804), President Jefferson in 1805 sent Lt. Zebulon Pike to explore this region, and in 1819 a detail of soldiers established Fort Snelling at the mouth of the Minnesota River seven miles below the Falls. Shortly thereafter a government sawmill was built at St. Anthony Falls.

When the first commercial use of this waterpower was made in 1847 this cataract was near the end of its natural life. The caprock, about 12 feet of hard Trenton limestone, overlies a soft St. Peter

sandstone which was undercut by the falling water. The thin cap extends but 12,000 feet above the present brink of the Falls and in the natural course of the rapid recession of the Falls the caprock would surely have been worn completely away within at most a few centuries, for recession by normal erosion was 375 feet between 1860 and 1869. This would immediately transform the vertical falls into rapids of moderate slope.

The process of stripping off the caprock was tragically accelerated when a six-foot tunnel was driven for a millrace through the soft St. Peter rock from Hennepin Island below the Falls to Nicollet Island above. Excavation began at the lower end in September, 1868, and on October 4, 1869, it reached the lower end of Nicollet Island above the brink of the Falls. Now a rift through the Trenton caprock appeared above the Falls and the tunnel was flooded. A big whirlpool appeared at the rift and only heroic measures could prevent the rapid stripping of the remaining caprock.

My father told me when I was a child of that hectic morning when the alarm was given by all fire whistles and church bells. It was a Sunday, I believe, and probably the church of which he was pastor had few able-bodied men in the audience, for all available men and teams were requisitioned to dump brush, hay and stones into the vortex. These measures failed. A cofferdam was then built around the crevasse, which temporarily checked the flow. The necessary $10,000.00 was raised by subscription and the work was finished on October 20. New breaks appeared repeatedly thereafter and in May, 1870, an engineer was employed who drew specifications for an apron of timber and masonry, which was built. But none of these devices were adequate and experiments continued for several years. The federal government finally came to the rescue, building a supporting dyke 2,000 feet long and 40 feet deep under the caprock. This was completed in November, 1876, and still holds the Falls where the millers want them. Of the cost, $545,000 was appropriated by Congress and $334,500 by the city. This was a good showing for a city whose population in 1872 was only 18,316 people.

The "Government Works" at the Falls were nearing completion when the Young Naturalists began negotiations with the engineer in charge. The minutes of February 25, 1876, report that their request for opportunity to inspect the works was granted, and Dr. Roberts tells me that under the guidance of Mr. Gillespie they spent an afternoon examining the masonry underlying the "apron" covering the Falls. The writer of these notes on a recent visit to the Hoover Dam in Boulder Canyon was taken down through the elevators and the tunnels into the bowels of that vast mountain of concrete. The inside view of this triumph of modern engineering was a great event in my life; and yet I doubt if this thrill of the septuagenarian could rise to the level which these 'teen-year old boys experienced in 1876.

At the meeting of Sept. 11, 1876, Mr. Griswold read a paper on "The Sun" and "Mr. Herrick gave notice of an amendment to the consitution at the next meeting. . . . Mr. Griswold moved that the 'Farmer's Union' be adopted as the 'Organ' of the society. Considerable talk on this motion resulted in nothing definite." Mr. Herrick read a paper on "The Trenton Limestone." An abstract of this, as already mentioned, was published in The American Naturalist for April, 1877. On Oct. 2, 1876, it was "moved and seconded that the secretary be required to keep a list of the pamphlets, &c, which have been or may be presented to the society and act as librarian. Carried."

On Oct. 9 there was no quorum. In the minutes of the following meeting, Oct. 16, we read: "Names of birds handed in by Mr. Roberts. Names of corals also handed in by Mr. Herrick. General discussion. The operation of chloroforming a snowy owl to produce death

was successfully performed by Mr. Roberts in the presence of the members of the society. Moved and seconded that the society adjourn. Carried. — Leon E. Lum. Sec.''

At the semiannual meeting, Jan. 8, 1877, reports were received from the president, treasurer and chairmen of the following committees: Ornithology, T. S. Roberts; Entomology, C. L. Herrick; Botany, R. S. Williams; Conchology, F. P. Clough. On Jan. 29, ''Mr. L. E. Lum read an interesting paper on Physics the same being his report on this subject as chairman of the committee.'' These five reports and the report of F. S. Griswold of the committee on Geology are now among the records of the Society and will receive further notice in another article. On Feb. 12, a paleontological list was handed in by Mr. Herrick. At the meeting of March 5 there was an ''address by Mr. Herrick'' on evolution, especially as exhibited in bird lice.

In the minutes of subsequent sessions we find the following items. April 9, 1877. ''Moved and seconded that the society extend a vote of thanks to Mr. Herrick for identifying and labeling the mineralogical specimens in the collection. Carried.'' April 23, 1877. ''Reading by Mr. Griswold, Subject. 'Blowpipe Analysis, Directions for,' followed by general and informal practice with Blowpipes kindly obtained for the occasion by Messrs. Herrick and Griswold, together with material upon which to experiment.'' May 7, 1877. ''Some unimportant experiments by Mr. Roberts illustrating the Effects of Ammonia Gas upon the colors of flowers. General discussion. Moved and seconded to adjourn. Carried. — T. S. Roberts, Sec. pro. tem.''

June 4, 1877. ''Reading by Mr. Williams. Subject. 'The Dodo.' Reading by Mr. Lum. Subject 'Phlogiston.' Business called for. Moved and seconded that the society find out whether a botany of the Northwestern flora has been published and if so to purchase it. Carried.'' June 18, 1877. ''Paper by Mr. Herrick on the Embriology of the Common Hen written from personal observations. General Discussion.'' July 2, 1877. ''Address by Mr. Herrick on the position of the old bed of the Mississippi River as shown by the geological survey of the county and how from data obtained during the survey an approximation of the date of the glacial epoch has been arrived at.''[6] Jan. 28, 1878. ''Mr. Herrick gave the society a short account of his trip to the southwestern part of the State recounting some of the peculiarities in geological formation and some of the birds and plants observed and collected.'' On June 3, Mr. Roberts presented a narrative of a collecting trip, and on Aug. 26 and Sept. 23, 1878, Mr. Benedict Juni reported ''general scientific notes from L. Superior'' and ''some particulars concerning the natural history, geology, &c of the North Shore of Lake Superior, which were very interesting.''

The officers elected on July 1, 1878, for the ensuing term were, President, Mr. Williams, Vicepresident, Mr. Roberts, Secretary, Mr. Herrick, Treasurer, Mr. Lum. At the expiration of this term the society seems also to have expired, probably because of scattering of the membership. The last entry in the minutes is of Nov. 18, 1878, as follows:

''Society called to order by the president. Roll call. Minutes of last meeting read and approved. Reading by C. L. Herrick—'Method in History of Life' (Prof. Winchell). Description and history of the Radiometer by T. S. Roberts. Discussion. Moved and seconded to adjourn. — C. L. Herrick, Sec.''

In addition to these minutes, the other documents in the files of the society yield some instructive views of the workings of these young minds and of the stage of development of natural history then attained in their community. A digest of these papers and a sketch of the subsequent careers of the three leading members is in preparation.

[6] Professor Winchell's estimate of the time elapsed since the close of the last glacial epoch was 7,803 years. His account of the recession of the Falls from the mouth of the Minnesota River at Ft. Snelling, a distance of about eight miles, is in Vol. 2 of the Final Report of the Minnesota Survey, 1888.

SCIENCE AND THE PROBLEM OF HUMAN VALUES

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SOME years ago a distinguished American scientist said in one of his textbooks:[1]

> We live in a world of values. We have material standards of comfort, and moral standards of conduct; and we eat, and drink, and dress, and house our families, and educate our children, and carry on our business life, with these standards more or less definitely before us. We approve good manners; we try to be honest; we should like to be cultivated. Everywhere and always our ordinary living implies this reference to values, to better and worse, desirable and undesirable, vulgar and refined. And that is the same thing as saying that our ordinary living is not scientific. It is not either unscientific, in the regular meaning of that word; it has nothing to do with science; it is non-scientific or extra-scientific. *For science deals, not with values but with facts.*

This is a most important declaration concerning the province and purpose of scientific inquiry. It is important because it is not merely the peculiar and personal point of view of the late Professor E. B. Titchener, but rather because it represents a concise statement of the consensus of opinion of scientists in general, even though few of them may have bothered to draw the distinction which he pointed out.

To say that while we live in a world of values, and that although the satisfactoriness of our existence depends upon our modes of adjustment to these values, science can do nothing for us in our endeavors to make such adjustments, is to disqualify science for dealing with matters that concern us most, and hence to discount the part which it can play in human affairs. Such a conclusion naturally challenges one's interest in an era so predominantly scientific as this.

In former ages of the world's history this severe delimitation of the functions of science would not have created the dilemma which it obviously creates to-day. Throughout the Middle Ages and later the authority and competency of the normative disciplines, such as logic, ethics, and esthetics, to deal with all questions of value were not successfully challenged. To-day, however, the presuppositions, and the canons, or norms, upon which these ancient and honorable disciplines are grounded are being scrutinized and their authority challenged everywhere except possibly within the sphere of influence of the University of Chicago, where, it would seem, a return to these disciplines is being looked upon with favor. There are, of course, ecclesiastically fostered educational institutions which have never departed from their medieval heritage in these matters. These would naturally prefer that the traditional separation between fact and value be maintained.

However, as between a return to the conventions of medieval thought and a consideration of the possibility of extending the scope of scientific inquiry so as to include at least certain aspects of the tabooed question of value, I believe that it is more in harmony with the modern temper to adopt the latter alternative. At any rate there seem to be sound reasons for holding that psychology, contrary to the dictum of the noted psychologist quoted at the outset, is one science which can not consistently waive

[1] Titchener, E. B., "A Beginner's Psychology," Macmillan Co., N. Y., 1915.

its responsibility for dealing with the problem of human values. In a peculiar way psychology must admit that it is human and that nothing which is human can be alien to its interests.

First, however, let us see if we can find any explanation for the fact that this question is to-day clamoring for attention with an insistence that is characteristic of our times. For an explanation of this fact one needs only to turn to the ideological struggles of the Old World, which have requisitioned all the resources of modern science for the destruction of those values which constitute what we are accustomed to think of as the substance of civilization. Here we see science, in total disregard of its responsibility for social values, prostituted to the ignoble task of aiding in the destruction of the very civilization it has helped to build. The mere *fact* that in doing so it is leading toward its own ultimate suicide should at least appeal to the curiosity of the scientific mind, however indifferent it may be to the *value* aspects of such an eventuality.

By waiving all responsibility for questions of value, science would step aside from most of the world-disturbing issues of our day, for these issues are issues of value, rather than of fact. Without doubt the most far-reaching and disturbing issue of our times, for example, had its origin in the Russian revolution. The issue there was clearly one of value, not of fact. The questions as to how many men own land in any country, and how much they own, are obviously questions of fact, and the answers to them are easily arrived at by methods of inquiry that are familiar to science. But the question as to whether it is a *good thing* for men to be permitted to own land at all is a question of value, and the answer to it, according to Professor Titchener, and according to the widely accepted tradition concerning the functions of science, lies completely outside the range of scientific inquiry, for "science," we are told, "deals, not with values but with facts." And so likewise with other vital issues of our times and our country, such issues, for example, as those of capitalism, socialism, labor-unionism, militarism, democracy, public ownership of utilities, competition versus cooperation, protective tariff, international trade agreements, ship subsidies, farm subsidies, race relations, and so on and on.

In all of these matters the really vital issue is, Which of the alternative policies would be for the best interest of society? The *facts* concerning these issues are accessible and hence do not necessarily lead to controversy. It is when we come to deal with the question of the relative merits, or values, of the alternative policies that we find the sources of disputes, conflicts, hostilities and war.

The dilemma with which modern society seems to be confronted might be stated as follows: Either we must conclude that our conception of the scope and methods of scientific inquiry can and should be readjusted and broadened so as to include in some measure these hitherto disregarded social problems, or else we must abandon the entire realm of values to the pure moralist, who seems these days to be fighting a losing battle, or else to the speculative philosopher with his normative disciplines, which hark back to the Middle Ages, disciplines whose influence on the lives of men grows less with time.

In recommending the adoption of the first of these alternatives one might also suggest the advisability of clarifying the distinction between "pure" science, so-called, and the "impure" variety commonly known as applied science. President Hutchins of the University of Chicago has brought this matter into the foreground of attention in current educational discussions. He thinks that the

invasion of applied science into higher education is one of the vulgarisms of our time, and is a main cause of the anti-intellectualism that characterizes our higher learning in America. Technology and vocationalism, in his opinion, have the effect of depriving universities of their only excuse for existence, which is to provide a haven, where, in cloistered seclusion from the madding crowd the "search for truth may go on unhampered by utility or pressure for results."

It has always seemed to the writer that, whereas it is well to maintain a distinction between pure science, or science motivated by intellectual curiosity, and applied science, or science motivated by interest in the practical results of discovery, this distinction becomes difficult at times to maintain. Such a distinction might be maintained between the rare genius and the common herd of mankind. Hence it goes without saying that it can not well be applied to the population in the average higher institution of learning. An investigator's interest in truth is not less affected by his interest in "results" if he happens to be concerned with the indirect instead of the direct consequences of his findings. A monograph, for example, on the theory of relativity, or on cosmic rays, may not yield cash dividends from industry, but such things do sometimes bring about promotions and other valuable considerations. Surely we could not say that the pure scientist is so unlike other human beings that he is influenced not at all by the practical results of his labors. There are, to be sure, martyrs in every field of human endeavor, but they are so few and far between in university halls that it hardly seems necessary to provide for them in the budget.

Furthermore, laying aside all traditions and theoretical considerations, it does not seem that the close alliance between the biological sciences and the practicalities of medicine has made them less capable of "search for truth." Neither has the alliance between the physical sciences and industry, which has been so strengthened in recent years, lessened their capacity for scientific research. So far as one can see it has not even narrowed the scope of scientific inquiry, but has broadened it, as numerous research laboratories maintained by industry will testify.

The pure scientist has always maintained that one can never know what practical consequences will accrue even from the most theoretical sort of inquiry. And there are many instances in the history of science to support this contention. Now the applied scientist can, on the same principle, say that one can never know what results of great theoretical importance will accrue from pursuing, in a scientific way, questions of practical moment. The history of modern science especially can furnish many instances to support this contention.

The truth of the whole matter seems to be that where one's findings and conclusions bear upon and make important differences in human affairs, they are more likely to be checked and their errors pointed out, than they would be if they had no practical consequences at all. Such checkings, it goes without saying, makes for higher, rather than lower, standards of scientific inquiry. When a person permits an overwhelming interest in the results of his work to tempt him to draw hasty conclusions, such a person has simply failed to maintain proper standards of scientific procedure, an error to which theoretical as well as applied scientists are, and always have been, subject. The fault, then, in such cases lies not with the objectives, but with the methods of inquiry.

No more intensely practical problem could be imagined than that of social values. In our present state of confusion as to the jurisdiction of science in the case, and in the absence of other ade-

quate agencies for dealing with it, there is widespread fear that all our modern scientific achievements will but hasten the doom of civilization. It is therefore a distinct disservice for educational leaders to endeavor to heap contempt upon science for undertaking to deal with the serious practicalities of life, or to "humanize the utilities," as modern education is accused of treacherously attempting to do. Fortunately, most sciences are prepared to accept the opprobrium of this sort of treachery. They seem to prefer it to that of a pathological escape into the contemplative seclusion of the medieval cloister.

It seems high time to break up this ancient tradition of intellectual royalty and substitute a grouping of the sciences based upon the more democratic conception of the division of labor. The two main functions of science are explanation and control or application. In such a grouping explanatory science must always have a place of central importance. But explanation for the sake of explanation, or explanation as mental exercise, or mental discipline, can hardly be considered moral in an age so beset by life-and-death problems as is our own. The pedagogy of such a pursuit is also open to serious criticism.

Explanatory science deals with cause and effect relations, and has as its aim the establishment of facts and laws. Applied science or technology, on the other hand, deals with problems of means and ends, and should aim at the production of values. Mr. Aldous Huxley thinks that it is a mistake to separate problems of scientific techniques from those of social values in professional training. Besides teaching young men to be mechanicians, for example, he thinks that we should teach them "to understand the ways in which machinery affects, has affected and is likely to affect, the lives of men and women." Certain it is that, in the absence of any feeling of responsibility in such matters, the more highly specialized a professionally trained person is, the more of a menace to society he can turn out to be.

Technology should assume responsibility for two somewhat distinct problems. In the first place it should seek to ascertain what sort of means will produce what sort of ends. This problem is as simple and as clear-cut, and as factual as are the problems of cause and effect with which explanatory science undertakes to deal, and the methods of inquiry called for in the case are not different from those employed in theoretical science. In the second place technology, or applied science, must, if it is to carry out its part of a joint undertaking, devise ways and means of determining which ends are good and which are bad. This is the crux of our problem. Granted that this is a field of inquiry from which by common consent science has for the most part in the past been barred, does this settle the question? It is not a new event in the history of science to explore hitherto unexplored territory.

Can the knowledge and the technical skills of our time be brought to bear upon the confusions that characterize human relationships everywhere? Upon the answer to this question depends the unsettled issue concerning man's ability to govern himself, for, in spite of our miracles of discovery and achievement we have been accused of living in a Stone Age sociology.

Among the sciences which deal primarily with man anthropology, ethnology and archeology are essentially explanatory. Psychology is both an explanatory and an applied science. It therefore seems in order to examine its competency and its obligation to deal with certain aspects at least of this problem of social values. There are other aspects of this complicated problem with which other social sciences, especially

sociology, are competent to deal. These of course can not be considered here.

First let it be said that to a psychologist of the present day it seems strange to hear the claim made that man lives "in a world of values," but that the very science whose proper study is the study of mankind must consider him in complete disregard of this environing world. In accordance with the principle of relativity, which is recognized in psychology as well as in physics, man's environment is to be regarded as a function of his behavior. His actions are always directed toward some object or goal. His emotions have reference to certain situations and conditions, and his thoughts are always *about something.* To think of man otherwise is to make of him a pure abstraction. We are forced, therefore, to conclude that psychology, in the very nature of the case, must either assume the responsibility of taking cognizance of the value aspects of man's environment or else abandon its *raison d'être* as presently conceived.

Furthermore, what, may we ask, is the nature of that mysterious something called value that all science must avoid the consideration of it? In what realm of reality does it abide, so as to be forever beyond the scrutiny of the scientific mind? While there are many divergences of opinion among psychologists and philosophers who have attempted to answer this question by giving definitions of value, there seems to be an agreement among the majority of competent writers on the subject that it can be defined, as all other natural phenomena must be defined, in terms of human experience. That which is an object of *interest,* we are told, is by that fact recognized as having value. Likewise, things which have the capacity to provoke *desire* are by that fact invested with value. Value, in other words, is generally conceived in terms of categories of human experiences, such as *interest, appetence, desire, yearning, craving,* etc., all of which are familiar to psychology and fall within the range of the inquiries which it has been prosecuting since it undertook to become a science.

Such a conception of value will at once be said to be subjective, and hence would preclude the possibility of generalizations in accordance with the requirements of science. "*De gustibus non est disputandum,*" or every man according to his taste, are not good mottoes for science, so it will be insisted. Whether our feeling experiences are any more subjective than our perceptual experiences would be a question too intricate and involved to be considered in this connection, though to all except the naïve realist the question is at least a valid one. The ideas we get of the physical objects before us are, we are told, derived from electrical discharges in the cells of our brains. The symbols or images which we construct to serve as the mental surrogates of these objects are, we are also told, no more like the reality of these objects than are the words we use to describe them. Hence the truth of Emerson's exclamation, "What a different world is walking about under your hat and mine!" He meant to say, I think, that what the world is to you or to anyone else depends more upon what is under the hat than it does upon what is out there.

And yet, the common ground of perceptual experiences, shared alike by all mankind, is sufficiently broad to furnish a foundation for all the vast accomplishments of the physical sciences. We have not as yet adequately surveyed the common ground of our affective experiences so as to afford a corresponding basis for the scientific study of the problem of human values. There does not seem to be any valid reason why such a study might not be prosecuted with this definite purpose in mind.

Since science does not pretend to be

competent to deal with ultimate reality it can not, of course, have anything to say about absolute good or absolute evil, granted that such values really exist. But in so far as we may think of good and evil hedonistically, that is, in terms of experienceable values, as all our authorities have defined values, then there seems to be good reason for assuming the competency of psychology to deal with them. The truth is that it has already made considerable progress in devising techniques for doing so, and has made some contributions in the application of these techniques.

Much of the work with these techniques has been done in the field of animal psychology. Some of the enthusiasts in this field are of the opinion that the essence of everything important concerning man's nature may ultimately be revealed through the continued analysis of the determiners of a rat's behavior in a choice point situation in a maze. Many others can not share this enthusiasm. It sounds too much like poetizing about the flower in the crannied wall. However, it is out of such simplified and controlled experimentation that we have been able to develop some of our most valuable procedures. The experimental attempts to measure social attitudes might be considered to admit of methodological refinements comparable with those which have been achieved by experimenting with rats in a maze. The pure scientist might, of course, resent the prostitution of his study of rats as rats to practical human ends, but fortunately not everyone can share his resentment.

If we define the socially good as being that which, in the long run, people, in the exercise of free choice, express a desire to perpetuate, we have a means of determining at least this sort of human value by scientifically satisfactory procedures, thanks to the rat in the maze. Voting, if it is to be a true expression of public preference, must, of course, be free from constraints and from fear, and, if it is to be socially beneficial, must be exercised in the knowledge of the merits of the issues at stake. Voting pro or con, assuming such conditions to exist, would seem to give quite as valid evidence of satisfactoriness or unsatisfactoriness, liking or disliking, that is of values, as the corresponding techniques employed in the study of animal behavior. Democracy, let it be noted, is the only form of government which can meet these conditions of scientific procedure. Let the prophets of doom turn from their prophesying and urge the exploitation by the democracies of this crucial advantage.

But the root of the difficulty of making politics scientific is not necessarily the impossibility of devising a scientifically dependable methodology, as has been indicated, but rather is it to be found in a veritable tangle of stubborn and stupid social traditions. We have come to accept the politician and all his ways as a sort of necessary evil. We are quite aware that the typical politician distrusts scientific knowledge, and has a holy horror of experimentation, which is the glory of scientific procedure. A defeated politician does not stop at *believing* his opponent's policies will not work; he proceeds at once to do all that he can to see to it that they shall not be permitted to work, and is honored as a faithful party man in doing so. Behavior that would put scientists in oblivion will put politicians in the seats of the mighty. Democracy, as a result of this tradition, remains on the level of the ancient trial by combat and will continue to do so until we adopt more scientific modes of evaluating public policies.

Picture a scientist sounding an alarm against a fellow scientist for suggesting new ways of doing old jobs. The typical politician, that is, the man who survives in office by the art of "playing politics,"

is almost a neophobiac. To the typically scientific mind nothing is so welcome and stimulating as new modes of thought, new interpretations, new technical procedures. Mr. Charles Kettering, of the General Motors Corporation, is quoted as saying at the American Club in Paris in 1933 that "because we are unwilling to take change-making as part of our everyday life, changes are forced upon us and we say, 'this is catastrophic.' I do not believe that you will ever get civilization or government of any kind on a sound basis until you appoint a cabinet member on change-making, logical change-making, because you can not keep change from coming." The industrialists who view with alarm all departures from the policies of the founding fathers of business are quickly and automatically eliminated. Such people survive and thrive only in the field of politics.

Picture a scientist trying to convince people of the soundness of his theories by beating drums and blowing horns in their ears. Picture a scientist who would repudiate experimental procedure. Only politicians are permitted with impunity to do this sort of thing. It is one of the inexplicable anomalies of our scientific era that we continue to subject ourselves to the leadership of those who, in the administration of public affairs, do such violence to the fundamental principles of scientific practice. Only the realization that this sort of policy is infinitely more dangerous to-day than it has ever been before can bring us to the grim determination to revolutionize our methods of dealing with problems of social values.

Once we accepted the rhythmic succession of economic prosperity and depression with a fatalism that was nothing less than primitive. Economists seem now—at least some of them do—to be persuaded that economic plagues, like other sorts of plague, are subject to human control. Our society is subject to another kind of rhythmic succession of good and evil, namely, the succession of rotten politics and reform movements. The possibility of dealing with this evil rhythm, which we continue to endure with the same primitive fatalism, is, in the writer's opinion, contingent upon the possibility of dealing scientifically with the problem of human values.

THE AMERICAN ACADEMY OF ARTS AND SCIENCES

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In the recently issued pamphlet entitled "The American Academy of Arts and Sciences, 1780–1940" (Boston, 1941) the present writer was afforded an opportunity to review briefly the past accomplishments of the second oldest scientific society in America.

The Royal Society of London, from its formal organization in 1660, was the principal scientific body to which the American colonists turned, a number of whom entered its membership or contributed papers to the *Transactions*. An attempt was made at Boston in 1683 to form a "Philosophical Society," and Cotton Mather, one of the prime movers in the enterprise, did creditable scientific work, which was later reported in Europe. When the young ex-Bostonian Benjamin Franklin sought to join a scientific society in Philadelphia and discovered that there was none, he organ-

ized his own, the "Junto," in 1727. Later, he issued his appeal for an American Philosophical Society in 1743 and laid the foundations for an organization of wider scope. By 1769 the remnants of these two bodies had coalesced and the merger resulted in a vigorous scientific career on the part of the American Philosophical Society in the closing decade of the eighteenth century.

Needless to say the successful enterprise was watched with much interest and almost envy by such civic-minded men of Massachusetts as John Adams and James Bowdoin, who soon dreamed of launching a similar enterprise in their own commonwealth. It was notably the experiences of John Adams, while in France representing his country in its struggle for independence, that started the chain of events leading directly to the formation of the American Academy of Arts and Sciences as he relates in his "Memoirs":

> In France, among the academicians and other men of science and letters, I was frequently entertained with inquiries, concerning the Philosophical Society of Philadelphia, and with eulogiums of the wisdom of that institution, and encomiums on some publications in their transactions. These conversations suggested to me the idea of such an establishment at Boston, where I knew there was as much love of science, and as many gentlemen who were capable of pursuing it, as in any other city of its size.
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> In 1779, I returned to Boston in the Frigate La Sensible, with the Chevalier de la Luzerne and M. Marbois. The Corporation of Harvard College gave a public dinner in honor of the French Ambassador and his suite, and did me the honor of an invitation to dine with them. At the table, in the Philosophy Chamber, I chanced to sit next to Dr. Cooper. I entertained him during the whole time we were together, with an account of Arnold's collections, the collections I had seen in Europe, the compliments I had heard in France upon the Philosophical Society at Philadelphia, and concluded with proposing that the future legislature of Massachusetts should institute an Academy of Arts and Sciences.
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> . . . I entreated him to propagate the idea and the plan, as far and as soon as his discretion would justify. The doctor accordingly did diffuse the project so judiciously and effectually that the first legislature under the new constitution adopted and established it by law.[1]

The fact that patriotism ran high as the Revolutionary War was being waged to a successful conclusion made it easier to plead that Americans ought to attempt to promote the arts and sciences in their own behalf by organizing a distinctively American academy. The efforts of the founders to acquire legal recognition by the Commonwealth resulted in "An Act to Incorporate and Establish a Society for the Cultivation and Promotion of Arts and Sciences." The charter thus granted on May 4, 1780, declared that:

> As the Arts and Sciences are the foundation and support of agriculture, manufactures, and commerce; as they are necessary to the wealth, peace, independence, and happiness of a people; as they essentially promote the honor and dignity of the government which patronizes them; and as they are most effectually cultivated and diffused through a State by the forming and incorporating of men of genius and learning into public societies. For these beneficient purposes,
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> Be it therefore enacted by the Council and House of Representatives in General Court assembled, and by the authority of the same: That a list of the incorporators follows . . . are hereby formed into, constituted, and made a Body Politic and Corporate, by the name of THE AMERICAN ACADEMY OF ARTS AND SCIENCES. . . .

And it went on to state that:

> . . . the end and design of the institution of the said Academy is, to promote and encourage the knowledge of the antiquities of *America*, and of the natural history of the country, and to determine the uses to which the various natural productions of the country may be applied; to promote and encourage medical discoveries, mathematical disquisitions, philosophical inquiries and experiments; astronomical, meteorological, and geographical observations, and improvements in agriculture, arts, manufactures, and commerce; and, in fine, to cultivate every art and science which may tend to advance the interest, honor, dignity, and happiness of a free, independent and virtuous people.

[1] John Adams, "Works" (C. F. Adams, editor, Boston, 1851–1856) IV, 260–261, in footnote.

Among those of the original incorporators that are remembered by posterity were Governor James Bowdoin, who became the first president of the academy, John Adams, Samuel Adams and John Hancock. By 1781, Benjamin Franklin, George Washington, Benjamin West, Ezra Stiles and John Warren had been elected into the society; in the following year Loammi Baldwin, David Rittenhouse and Jonathan Trumbull were among those taken into the fold. Thomas Jefferson was admitted in 1787, and Benjamin Rush in 1788. John Jay, Alexander Hamilton and James Madison were among the first men prominent in public life to be entered on the roster of the academy; while on the other hand, the names of the architect Charles Bulfinch and the painter John Singleton Copley evidence the wide range represented by the early membership of the academy.

Then, too, the rapidly expanding academy was becoming international in scope, for it could count among its esteemed foreign honorary members of the first decade d'Alembert, Lalande, Buffon, Euler, Priestley, Sir William Herschel, J. D. Cassini and that erstwhile American, Benjamin Thompson, then Count Rumford, residing in Bavaria, who became a member in 1789. His gift of what came to be later known as the Rumford fund was made in 1796. No award was made under it until 1839, when the chemist Robert Hare of Philadelphia became the first Rumford medalist in recognition of his invention of the oxyhydrogen blowpipe.

With the appearance of its first volume of "Memoirs" in 1785, the academy had meanwhile been launched on a career of publication. A preface to the initial volume, in addition to setting forth the aims of the society, contained a vigorous appeal to the "patriot-philosopher" to delve into the hitherto unexplored natural history of America. This same stout volume contains no less than fifty-four papers, exhibiting interest in a wide variety of topics ranging from "Account of the Transit of Mercury, observed at Cambridge, November 12, 1782" by James Winthrop to "Observations on the Longevity of the Inhabitants of Ipswich and Hingham . . ." by the Reverend Edward Wiggelsworth.

The first research project sponsored by the academy was an astronomical expedition undertaken in 1780 in collaboration with Harvard College, to what is now Ilesboro, Maine, to observe a solar eclipse. Although the Revolutionary War was still in progress and the British naval blockade rigidly enforced, the scientific party headed by Professor Samuel Williams of Harvard was permitted to land. Insufficient time remained to the astronomers to determine a suitable site of observation, the weather was bad, maps inaccurate, and the upshot was that when the eclipse occurred the astronomers to their intense disappointment found themselves just outside the path of totality. Their disappointment might have been less keen had they realized that Professor Williams's report in Volume I of the "Memoirs" of the academy contains what is perhaps the earliest conclusive description and drawing of the phenomenon commonly described as Bailey's Beads.

During its first decade the academy had made solid progress, and a new chapter in its history came with the inauguration of John Adams as its president in 1791, a part which he was destined to hold for almost twenty-five years. In the early years of the nineteenth century men with intellectual interests as far apart as those of Nathaniel Bowditch and Noah Webster were contributing materials to the "Memoirs." A little later Loammi Baldwin, the ornithologist Thomas Nuttall, the botanist William S. Sullivant, the geologist

Edward Hitchcock, and the astronomer William C. Bond were among the leading men of science in the academy.

Meanwhile Horace Mann, Edward Everett, Jared Sparks, William Cullen Bryant, John Greenleaf Whittier, Ralph Waldo Emerson and Henry Wadsworth Longfellow were representative of those who strove to keep the humanities from being crowded out of an academy becoming ever more engrossed in the physical and biological sciences as such veritable intellectual giants as Louis Agassiz, Asa Gray, James Hall, Joseph Henry and Jeffries Wyman—academicians all—loomed on the horizon. Shy Maria Mitchell, of comet fame, was the first and only woman to become a member of the academy, being elected in 1848. In the same year the "Proceedings" were commenced.

By the closing decades of the century such scientists as James D. Dana, H. A. Newton, Simon Newcomb, George W. Hill, Edward C. Pickering, Josiah Willard Gibbs, T. U. Richards, Seth C. Chandler, Samuel P. Langley, Alexander Graham Bell, O. C. Marsh, Joseph Leidy, A. S. Packard, H. P. Bowditch and Charles W. Eliot had come into prominence in the academy which celebrated its centennial in 1880. Among the names of men in the academy eminent in the humanities and in the social sciences during those years one finds Centennial Poet Oliver Wendell Holmes, Charles Francis Adams, George Bancroft, Henry C. Lea, Lewis H. Morgan, W. G. Sumner, Francis A. Walker, B. L. Gildersleeve, H. E. Van Holst and Henry Adams. There were also to be found men of public affairs and large philanthropies like Augustus Lowell.

A cursory glance at the roster of the academy reveals at once a notable galaxy of foreign men of science elected into membership during the course of the nineteenth century, including Humboldt, Thomas Young, Faraday, Arago, Maxwell, Lyell, Liebig, Darwin, Leverrier, Joule, Oersted, Clausius, Helmholtz, Kirchhoff and William Thomson. Among the more important foreign men of letters and affairs who became members in the nineteenth century were Guizot, John Stuart Mill, Thiers, Ruskin, Gladstone and Tennyson.

There figure in the annals of the academy during the early decades of the present century such names as those of A. A. Michelson, T. C. Chamberlin, Elihu Thomson, Percival Lowell, Alexander Agassiz, W. T. Sedgwick, Maxime Bocher and Charles P. Steinmetz. The academy, celebrating its one thousandth meeting in 1910 with a dinner typical of colonial times, heard Professor Edward C. Pickering forcefully reiterate the original aims of the academy when he sounded as his keynote that, "The real objects should be the increase and diffusion of knowledge, the first by research, the second by its publication."

In recent decades the academy has continued its career of fostering the growth and dissemination of the fruits of scholarship. In the present troubled world, the academy still stands as a beacon of the continuity of international learning.

AN ANTHROPOLOGIST IN RUSSIA. I.

By Dr. A. HRDLIČKA

CURATOR OF PHYSICAL ANTHROPOLOGY, U. S. NATIONAL MUSEUM

Foreword. The writer has made three trips to Russia, in 1909, 1912 and 1939. He had chances to see large parts of the country, including Siberia and Mongolia, and the people of the same. He was everywhere aided generously by the Russians, and understanding their language had a valuable advantage. The notes that are to follow were made on the memorable trip of 1912, when in search of American affinities he was able to visit parts of southern Siberia and Outer Mongolia. They are the faithful simple records of a student of humankind and one fond of nature, for his wife who had to stay at home. By this day they are largely already but matters of history. Between 1912 and 1939 everything in Russia, Siberia and also Mongolia, has changed, was almost reborn or remade. What in the earlier years were but vast steppes or forests are to-day in many parts rich farms, with new and bright settlements; and what in 1912 were mere country towns were now found to be unrecognizable large industrial cities. Even the types of people, or at least their aspect and bearing, have changed, so that the whole population appears now rejuvenated and re-energized. It is truly a new Russia, new, virile and modern yet its own kind of a world—only the kindness and cordiality of the people remain as they were. And the same is true, from what was learned, about Mongolia.

In 1911, Colonel D. C. Collier and Dr. Edgar L. Hewett, the former in charge of the Panama-California Exposition that was to be held at San Diego, California, in 1915, and the latter director of the anthropological exhibits, approached me for a plan of an original exhibit in physical anthropology. There were consultations, the plan was submitted by me and accepted, and a sum of money was deposited with the Smithsonian Institution to be disbursed under my direction. The plan comprised the preparation of five halls of exhibits, the first devoted to man's evolution and antiquity; the second to his development from birth onwards or his life cycle; the third to man's racial and individual variation; the fourth to human decline, pathology and elimination, and the fifth to anthropological library, instruments and methods. As no such a comprehensive exhibit had ever before been attempted and there was not enough of the needed materials at hand or even in existence, and in order that both the Smithsonian, under whose auspices the whole work was to proceed, and science in general might benefit as much as possible from the occasion, it was decided to send out a series of expeditions to Europe, Asia, Oceania, Peru, and to the St. Lawrence Island in the far northwest, between Asia and America. Two of these expeditions, that to Siberia and Mongolia, for a study of some of the peoples there and of their affinities with the American Indian, and that to Peru, for pathological materials, were reserved for myself and carried out in 1912 and 1913. Both proved highly fruitful as well as interesting, enriching the memory with whole lines of new experiences, some of which may be worth recording. The following are the day-by-day notes on the trip to Russia and Mongolia.

St. Petersburg, July 7, 1912. Over Europe since late in May. Attended a scientific congress in London, scoured France, Belgium, Germany, for needed specimens and preparations, and eventually reached Russia, where I am now impatiently waiting for necessary documents, and learning Russian. Have as yet no permission for Siberia and as matters look now will in all probability get none for Mongolia. Am bound nevertheless to go and try to do what I can with some friendly letters, permission or no permission, until they send me back; but if I have to go thus it will be far from pleasant. There still seems much resentment felt in this country

over the abrogation of the Russo-American treaty by the U. S. which was the work, they say here, of our Jews. Another anxiety are my boxes with instruments, etc., sent here from the Smithsonian. Have been unable thus far even with the help of our people to find if they are here. Have also sent here to the Embassy, through mail, some printed blanks from Paris, and find that they are held at the custom-house. Some of the people whom I have to see about the Far East are on vacations and I have to go after them into the country, even to Finland. And the language is difficult in the beginnings. So there are troubled waters enough. But I may yet find a way through it all; have gained one influential friend; and am healthy and vigorous.

FIG. 1

July 10. This is how it went yesterday. 9 A.M.—coffee, restaurant half a mile distant, Polish; in the hotel here prices too high, of mornings everything smells yet of last night and life is barely commencing, and all service venal, after fees only. At 10 a visit to the Ministry of Foreign Affairs in search of one who could perhaps help with Mongolia—he will not be here till 11. Walk the streets. Come back at 11—not there yet. Go again and come back 11:30—still not there; go to his office, and there after some ten minutes am told that he will not come to-day. Get his house address and go to search him there. Walk an hour over the hard pavements and at last find the house—only to be told that the man I want has gone somewhere and will not be back till evening of the next day. Walk again—no car, no drozka about—and search for a restaurant for lunch but find none; with limbs weary reach finally the Museum of the Old Academy where I know two or three people, only to find that they also are out of town, for this is the period of vacations. But the one man who is there, an assistant, treats me to a glass of plain tea, at 2:30 P.M. Another good walk to a car and a trip to the principal Bibliothèque, where I understand my boxes from the Museum would most probably be. Meet the Secretary—and he tells me nothing has come. He has however a letter in which the Smithsonian informs him that the boxes were shipped the 31st of May, but when they will get here he knows not. Well, there is nothing to be done; if the boxes do not come before I leave, they will have to go back and I shall have to get along the best I can. They contain my photographic outfit, blankets, clothes, etc.; but I have a smaller camera with me. Swallow some lunch nearby and then to the Finnish station, for I must still reach Finland this afternoon. At 4:30 on train, at 6:15 at Raivoli, Finland, then 5 versts in an old cab, and I am with Professor Radloff, whom I know from before, director of the Ethnographic Museum and president of the Society for Exploration of Central and Eastern Asia. He is a highly esteemed old man and receives me very cordially. The girl brings a cup of coffee and some biscuits; we talk and talk. He will help me with letters to the authorities in

Siberia and Mongolia. Will make me, still better, an "agent" of the Imperial Geographic Society, which is an official body greatly respected everywhere in the East by all Russians. At 8:20 my izvoschik comes back for me. At 8:55 A.M. again on train for St. Petersburg; arrive 11 P.M., swallow three or four little bits of sandwiches at the station and a glass of hot tea, take a car, then another, and just before 12 A.M. back again where I started from this morning, in the Hotel de France and my little "chambre." Slept like a stone till quarter of 7, though dog-hungry. To-day at 11 the Ministry of Foreign Affairs again, just to try my reviving luck; then to the American Embassy; then the anthropologists at the Museum of Alexander III; and then the custom-house, if time permits, and after some information. But do not mind now anymore. . . .

July 13. 12:30 p.m. Wonders still take place and good fortune still can smile broadly, even in Czarist Russia. Am on the fast Siberian express leaving St. Petersburg, bound for Krasnoyarsk, central Siberia, where the train is to arrive six days hence. The Ministry papers, am assured, will go after me in a few days; have a pocket full of Russian letters of introduction; have engaged a nice young man, a University student, speaking English to meet me in Siberia and he will bring my boxes, which have at last come on a boat not yet unloaded. Besides all of which the sky is bright and the ground green, and I am beginning again to feel my old good-natured self. But I did not know until within twenty-five minutes of the departure of the train whether I should be able to leave. Will not mention all done and walked and waited since I last wrote, but now I am on the fastest and best train they have here. Only this—as a lesson. I saw the officials of the Ministry of Foreign Affairs at last, thanks to my influential new friend, Prince Ukhtomsky; and they very kindly made us to understand that the delays in issuing my permissions were due to the fact that they had received from our Embassy a letter which they could not quite understand. This letter was written, I found later, by a young woman interpreter at the Embassy who was French and did not know good Russian. . . .

3:30 p.m. Just had a splendid lunch on the train, for 75 cents: fish with shrimps and mushrooms, meat with vegetables, and čaj, the hot, sweet Russian tea with a slice of lemon in it, with which the good moist black Russian bread and sweet butter. Am alone in a coupé—the porter, to insure a bigger fee, has already called my attention to it, saying that he has put the one who was to share with me into another compartment. All want fee here, as elsewhere in Europe, but they endeavor to earn it and are not rude about it. The more I learn to know them the more I like the Russians. . . .

Ride through extensive flat country—all is flat for great distances about St. Petersburg. Most of the ground is covered with young spruce and birch forests of different ages, with grassy patches between, unutilized, and far apart a "dierevňa"—a small but mostly large drab log-house village with a round of fields and meadows about it, on which graze cattle with big heads and horns, and work women, girls and older men, piling up hay. Cross the Volkhov River, bigger than the Seine, but here no one takes any notice of it. There are barges with square sails which remind one somewhat of the Nile. Now and then pass a clean wooden station with the characteristic bearded grizzly Russian moujik faces. . . . Towards evening, pine, spruce, fir, birch forests, from saplings to half growth. Dead patches, after fire; cords of cut wood in the forest; rarely a human being—lone postman, a peasant, a girl—one wonders where they are from and why so far from

everything. A village of about ten frame or log houses with poor fields, and with hundreds of cords of cut wood. Smaller and larger streams, with more or less muddy water. Large sandy patches along the rails, sandy roads. Again great stacks of wood, the fragrance of burning branches. Here and there swamps. The bleak hand of the north visible. In the south such lands would soon be fit for cultivation, but here they stay just wastes.

Now the train runs on a raised bank, the forest is so low that one can see many miles away, and it is like in the pampas of Argentina, only all covered with small woods; not quite all, for there and again in another place is an agglomerate of a dark village, with a few red roofs, and in distance ahead the blue and goldened cupolas of three Russian churches in Tikhvin, a little city. These blue, green, grey and gold cupolas and spires of the Russian "pravoslavny" churches look everywhere chaste and beautiful, but most so amidst the green scenery. They seem the embodiments of pure prayer, of higher solace to the human sufferer. . . .

Once in a while rural or forest worker with shirt worn belted over the trousers, or a woman or girl with a white kerchief on her head. White, yellow, reddish, bluish flowers scattered through the grass; an occasional field of rye or potatoes or cabbage. And all the rest the self-same pine, spruce and birch.

Alone in my spacious compartment, undisturbed, and so can give myself fully to the odd world through which the train is passing. The "express" goes thirty miles an hour, and about every forty minutes there is a comfortable stop, the men oil the journal boxes, passengers step out and stretch limbs, the locomotive gets an additional supply of wood, children bring milk in bottles and sell to passengers, the bell rings, conductor whistles, everybody leisurely gets in, then another signal, a hardly perceptible start—and we merge deeper into northern Russia. I sit on a stepladder at the window and look and think and write, and feel happy as we go. A savory smell of supper comes through the spacious good cars, and again the smell of the woods and grasses. It is comfortably cool. What more for the while could one wish for. Some jackdaws—but strangely but few other birds; pools and ponds of water; and woods, woods, woods. . . .

8:30 p.m. Near sunset—days here are long. The red glowing celestial ball reposes a few moments on the tops of the low trees on the horizon. Supper—soup, fish, some kind of a game bird, little ice cream, and two glasses of golden tea with lemon (they serve nothing in cups unless demanded)—88 cents; and plenty of everything. No stinting on trains in Russia. An accident during supper—in passing one of the poor little villages some ignorant threw a stone and broke one of the windows of the dining car.

Pass two saw-mills. How homelike it must be for wolves in these endless low forests. And what a life it must be in those isolated villages, especially those far away from the railroad, alone in the vast green wilderness. Who could show such a life, truly and entirely—or has man even here conquered nature? The beds made, the long northern twilight is upon us and slowly deepens. . . .

July 14. Sunday. Bright peaceful morning, as if Sunday reigned everywhere. Had a nice clean bed, but it was cold and I wished I had my camel-hair blanket! Had to help with the coat.

The road is sandy, dusty, and everything got greyish over night, but the porter, who speaks Russian so clearly that I understand him readily, has made everything near neat again. Outside the scenery still much the same as yesterday, only more water, brown or rusty but clear, and the forests more spruce, more undergrowth, more dense. The villages the same but even farther apart, twenty,

thirty miles in cases. Some horses graze on a meadow, the Russian horse, with body medium or smaller as compared with ours, but a good-sized well-formed head and thick mane. They are generally red or brown in color and appear full of power. Little girls bring wild strawberries to the train, ten kopeks (5 cents) a full plate, but no paper, which probably in these small settlements is a very scarce article. Another good-sized river, the Sharia. A few birds. Plenty of grass going to waste—few people, few cattle—still too northerly.

The forest, for a wonder, this forenoon gives away! At first segregates in large patches and at last its remnants are only like scattered larger and smaller islands. The country is now uneven and covered with fields, but these still of mediocre quality. Windmills appear, wooden, uncouth, home-made like. A village or two are passed close and it is seen that the gable-shaped roofs are made of boards running not from side to side but from above downwards. There is no paint on the log-houses or roofs and everything, unless new, has the dull slaty color of old wood. Some goats and sheep are seen for the first time. The sky is getting cloudy, and it is as cold as with us about the middle of October, one could easily bear heavier clothing. Peasants are seen with peculiar open-work felt sandals, the "laptie"; some look as if made from straw, and are worn over a cloth wound about the feet and legs, which reminds one of the leggings of our Pueblo Indians. A boy stands at a little station barefooted and with his boots hanging over his arms—not a rare picture; the boots are expensive while the skin grows. . . .

As we near *Viatka* (now Kirov) a change in houses and other constructions becomes manifest, the roofs now slope in four directions instead of but two. The dwellings also are more square. There are large Λ-shaped sheds, for hay probably; and occasionally one sees half underground dwellings covered with earth, as we used to have in the Dakotas. The hand of the north.

Viatka is a sparse city with a cathedral of five cupolas, beautifully dark blue. At the station they sell all sorts of handmade wooden things, especially nice plates with carved motoe inscriptions, and Siberian gems. But the common people are disappointing. They are not of the good Slavonic type. They speak Russian and have doubtless some Russian blood, but are most likely largely of Finno-Ugrian admixture. There are seen often rather long faces with prominent cheek bones, mouth, and angles of the jaw, and with various shades of grizzly or pale hair and beard. And many look uncultured. They are, of course, the untutored peasants, but they are not like the peasants of Bohemia, Moravia, Poland, or more southern parts of Russia. The women look better though nothing to boast of. A true open Slavic physiognomy makes here and there a pleasing exception. . . .

Another good-sized river, the Viatka, after the town. More fields, but then again poorer country. . . . At 3 P.M. again all a young forest, except now and then a smaller or bigger clear patch.

8:30 p.m. No day passes without some returns, and so with this. Most of it was rather dull, with chilly, cold, overcast sky, poor scenery and uninteresting people, until near supper. Then the country became one mainly of fields and villages, and the people changed for the better, different, more intelligent, more lively. In all probability another strain, more Russian. But the fields are still not rich and we are evidently nearing still worse or a more unfortunate region, for as we stop at a station during supper Russian young men and women, probably University students, come in to ask aid for the hungry who through drought had no harvest last summer. And they pin to the coat of each one who contrib-

utes, and there are none who do not, a little bunch of green rye-tops, the harbingers of a better summer and winter this year. Here they are—I shall save them. Gave not much but gladly, and there is inside already a warm nook for these people. The masses are backward, but they only need awakening, as shown in every eye, every fiber of these youngsters. The girls in particular, they are not beautiful yet attractive, intelligent and refreshingly free from flimsiness either in dress or behavior. . . .

July 15. Monday, 6:30 a.m. Sun, bright morning; but at 7:30 cloudy again, and now rainy, cold. The country has changed again, there are now low hills and shallow basins—approaching the Urals. The ground too is more fertile. There are many fields, with cattle, geese; and there are numerous smaller villages. Bits of the forest remain, but cultivated ground predominates all over.

9:30 a.m. Slowly going higher—this train is surely no "speeder" in our sense of the term—we have made, I learn, on the average less than twenty-five and now are running about fifteen miles an hour. But it is all very comfortable and gives a good chance for observation. The hills are low, underlayed with horizontally stratified shale as near Pittsburgh, and it would seem natural to see coal mines and oil-pumps, but none are visible. The houses and villages are much like those before, with occasionally a red or green tin roof. The people preserve the better type, more Slavonic; and there is about them something interested, sympathetic and friendly, which one misses in other countries. If only it were warmer. What must it be here in winter!

10 a.m. Once more forest only, on all sides. . . .

5 p.m. Hard to write, so chilly. The thermometer shows 57° F., but the damp air makes it feel much lower; and the train can not be heated, they say, at this time of the year. They promise better once we get to Siberia.

Forests, or rather one vast forest, again since this morning, with only patches of clearing, sometimes far apart, and even there the young trees are sprouting in many spots wanting to retake what was their own. There was, however, a large town, Yekatierinburg (now Sverdloosk)—like an oasis.

Nevertheless the scenery is much nicer than yesterday, and in sunlight must in its way be beautiful. Now, towards the evening, the train runs through peaty levels which are overgrown by the trees more sparsely, often in bunches, with the higher parts of the ground among them covered with low grass interspersed with daisies and other little flowers—the whole looking like a fine natural park. But thick woods commence at the low hills behind; and a boy tells us the wolves come to the little settlements here every night, after sheep. Little more north bears come, also. This must be the country of which some of the older European folk speak "where the wolves give good night and the bears good morning." . . .

Not a fruit tree of any kind, not a dozen seen since St. Petersburg—can not stand the winters here; and though this is the midst of July twice already have I noticed the leaves of some garden plants wilted by frost. Yet it must be beautiful here in fine weather, and the people look sturdy, animated, good. . . .

At Yekatierinburg saw a mass of emigrants for Siberia. All poor, often in big worn leather coats, big caps and big boots, or with the legs wound in rags; but many of good physique, sturdy, and none dejected—surely good materials for the peopling of the wilds of Northern Asia.

In the villages it is a common thing, notwithstanding the chill and drizzle, to see a child running barefoot. No one outside in fact seems to feel the cold as we do here in the train.

See some women, and again others, in short skirts, high boots, a whitish kerchief on their head, and each with a scythe on her shoulder. Their backs are

somewhat bent from work, but they walk easy and surely do not look "downtrodden," or anemic, a good strong stock.

Pass a village of many hundreds of houses, the largest yet seen; but the houses are all alike and the dark dull color of the old wood, now wet, under the leaden sky and with the muddy roads, look gloomy. A church with its fine blue cupolas in the midst is like a fairy palace in comparison. But the view is lost in the forest before one can wholly consider the scene. The ever present daisy, quite the same as ours, is always with us, and so is the fireweed, which has spread over much of the northern parts of the globe.

6 p.m. See to our left for the first time what deserves the name of hills, but not great, not much more than those about Washington. If the Ural here is thus then it does not deserve the name of a "mountain" range. But where all is flat even a small hill becomes a "mountain," and there are parts where the range is much higher.

A little while yet and we will be in Asia. The notes for this day will already be finished in Siberia, the vast, concern-full, wonderful, unknown, the motherland of our Indian and Eskimo.

Sorry for all this fine grass hereabout that is going to waste; there must be tens of thousands of acres of it here, for it extends even into the woods. What flocks could graze here—and doubtless will in the future. . . .

A little station, children bring blueberries, and a young man a live porcupine. There is no insistent or unpleasant tone to the offerings, the prices are moderate, and sellers as well as buyers good-natured.

July 16. Tuesday, 9 a.m. Southwest Siberia, Asia! And one would only need to half close the eyes, so that the low young birch woods here and there looked more like cottonwoods, and one might be somewhere on the prairies in western Nebraska or Kansas. There is the same dark earth, the same drying grass, and here and there even a little patch of alkali. Much here already cultivated, and with only more moisture this would be a rich country. Once in a while a large shallow pond or lake—exactly again as in some parts of the Mexican plains. Nature repeats itself. Nor are the grazing cattle and horses missing, or even the distances, or straggling new settlements—only the dwellings are different, more log-houses, more sod on the roofs, less board; but the differences are not very material.

The air is warmer and the sky, though cloudy, shows patches of bluish. The wild vegetation has changed, too, as if by a magic. There is no more clover, no more fireweed here, nor even a daisy; instead what looks like a carroway-seed plant and yellow, white, pink and blue wild flowers, some of which I do not recognize. . . . Have passed a short time ago Petropavlovsk, a rather large town, lying at a tributary of the great Ob River.

P.M. The country changes but little, except that cultivation is becoming much less. On both sides there are now endless grass-covered steppes over which appear like sparsely sown smaller or larger patches of young birches. On the grassy levels between are seen now a herd of cattle, now stacks of hay, and then again nothing but wastes, with far away level roads showing the deep dark soil. Once in a while one, two, three men or boys on horses, or the characteristic small-wheeled Russian troika, or a woman turning some hay so it will dry better. The wild parsley has increased until now the levels are yellow with its flowers, like those of fennel.

Before Petropavlovsk saw the first Kirghiz or Tartars, dusky, mongoloid, but apparently quite sturdy people. Saw also two of their round tents. One of the men could easily have been an American Indian.

In places along the tracks piled-up

sections of snow fences, ready for winter —as in our Rockies. Patches of ground that show drought, but also small swamps or pools. At times the birch thickets recede to the very horizon and there appear raised above the ground in half haze, like a mirage—exactly as distant bushes on our prairies or brush along distant low banks along our rivers. Then again a region where the thickets occupy almost the whole vista—and then once more great worked fields, with thousands of hay-stacks, or long lanes of wheat or barley. On the other side a large shallow pond with a herd of cattle reposing close to it, like on a Dutch picture. An ideal country for grain raising and cattle and horses—until one doubts that this can be Siberia.

Pass a freight train, flat cars, on them some men, and a woman with bags—evidently the state does not mind if some one thus gets a cheap ride. Pass trains full of peasants, the migrants. Crowded in converted freight cars with small windows near the roof, sleeping on tiers of shelves. But their welfare appears to be looked after—one sees everywhere samovars in the cars and at every larger station there are for them free hot water and cheap provisions.

The Russians call the dead body a "pokoinik," the peaceful one; "nediele" (no-work), originally Sunday, is now a week; "golubčik," and "golubuška"—he- or she-love; and a wild flower is a "dikói cvietóchek." The whole language is soft and, when well spoken, very pleasing. I spend all my spare time learning and reading it, and light is coming. Like the language more and more and hope to acquire at least as much of it as I need in travel and work. There is not a foreigner on the train, except two Japanese, and they speak some Russian, so I can not but hear and learn. Only like everywhere there are but very few who have the fairies' gift of speaking with clearness and purity.

First little sage-brush—we must surely now be at the edge of our prairies. A girl in a pool, red skirt tucked in above knees, washing linen. Black sheep. Sod-covered low dwellings. A little station—women bring half-ripe looking, but sweet, small wild strawberries—use them also for preserves; have big buckets full, must be very plentiful. . . .

More Kirghizes—of brownish skin, peculiar round caps on heads—are Mohammedans—and peculiar shoes. Look at stations for a postal card that would be showing some of them, but in vain. As with us the last thing of interest to the vendors are strangely the local and especially the native people. . . .

Have made two friends on the train already, one a young Russian officer, the other a Russian engineer. The latter goes out with me at Krasnoyarsk, which will be already the morning after tomorrow. How "small" is Siberia—have barely begun to be acquainted with it and already off the day after to-morrow.

17th, Noon. A whole little village with sod-covered roofs; also half-underground sod-roofed houses with little windows. Saw once very similar things in South Dakota. Not Russian. . . .

The scenery keeps similar; yet since Nicolaievsk there comes a change, unevenness in ground, low ridges on horizons, birches higher, ground well covered with grass, and fields of grains. The earth itself is the same blackish earth as everywhere thus far in southwest Siberia, old loess, humus and alluvium. No stone in sight anywhere, and future architecture will be brick only. The black ground like ours in Illinois, and those grand rivers that can easily be utilized for irrigation—what a future; and what a future after the children of all these sturdy immigrants, brought up under these vast free skies, acquire education. There will surely then be a new Russia, a new great people, a New World in Asia.

(To be continued in April issue)

BOOKS ON SCIENCE FOR LAYMEN

MATHEMATICS FOR THE PHILOSOPHER

Mathematical Logic. Willard Van Orman Quine. xiii + 348 pp. $4.00. September, 1940. W. W. Norton and Company, Inc.

PROFESSOR QUINE'S book is far too technical for adequate notice here, and we must refer to the mathematical abstract journals for fairly detailed notices. The complicated printing and proofreading have been done with extraordinary care (page by page use with a small class disclosed surprisingly few slips, either of statement or of printing).

The impression a detailed reading made on at least one mathematician may have been shared by others. In spite of all its formulas, and the great skill shown in constructing proofs, the book is that of a philosopher rather than a mathematician. A class in philosophy would find here endless opportunities for metaphysical polemics. A class in mathematics, on finishing the book, might feel somewhat dazed, as if they had been present at the creation of a new heaven and a new earth: "God said 'Let there be an infinite set of so-called *axioms of quantification.*' And there was an infinite set of so-called axioms of quantification." It is not quite as simple as that, of course; the infinite set is merely 'specified' as a device to aid calculation. Mathematicians have long been addicted to specification. Without it, a large part of extremely useful mathematics might never have come into existence.

To the reviewer the most interesting part of the book was the concluding chapter, "Syntax." Here the author expounds his own derivation of Gödel's classic theorem on the incompletability of logic and arithmetic. It is not easy reading, and possibly it is one of those really deep things in mathematics that have to simmer a long time before they either boil down to a fairly stable solid residue or evaporate. One of the conclusions may be stated:

"Indeed, a notion of theorem capable of exhausting those logical formulae which are true and excluding those which are false will be definable only in a medium so rich and complex as not to admit of a model anywhere in the reaches of logic and the derivative body of mathematics."

For those who are willing to master a symbolism essentially simpler than that in more technical mathematics, the book can be recommended as a stimulating account of some of the main topics in mathematical logic. Much of the presentation has been influenced by the author's own work. This is nothing against it. What is the point in bringing out books which follow their predecessors like sheep going through a hole in a fence?

NOTE: Since the above notice was written, J. B. Rosser (*Bulletin of the American Mathematical Society*, 48, 1942, 21) has pointed out that "Unfortunately, the system of logic presented in this book admits the Burali-Forti paradox. This admission renders the system inconsistent. As a result the book fails in its primary purpose and will need serious revision." The first three chapters and (except for minor details) the last are unaffected by the paradox.

E. T. BELL

THE PHYSICAL SCIENCES AND THEIR APPLICATIONS

Science in a Changing World. Emmett James Cable, Robert Ward Getchell and William Henry Kadesch. xvii + 665 pp. $3.75. 1940. Prentice-Hall, Inc.

FOR the rapidly increasing number of adults who have developed a real interest in the physical sciences or in their applications and who wish to achieve a degree

of correlated understanding this survey of the elements of physics, chemistry, geology, physical geography and astronomy should be of real value. It is mature, very readable, well illustrated, sound and thorough without being technical. It is practical in the sense that every topic begins with common, well-known phenomena and then explores the reasons and explanations. Thus, without ever being didactic or deparmentalized, it engages the reader and gives him a better knowledge of the fundamentals of these various sciences than most college students would retain from a number of separate and more technical courses.

The authors are professors of geology, chemistry and physics, respectively, at the Iowa State Teachers College at Cedar Falls and have perhaps developed this book from a unified course in the physical sciences for education students. It would serve such a purpose very well. Surely every teacher in the elementary schools needs at least this much understanding of the world about us, though it is equally sure that few now have it. College professors in the separate sciences will object that such a survey does not go far enough nor deep enough, but the limitations on such a course are rigorous and only one who has attempted to make such a selection can commend the authors for the scope and level achieved. True economy of college time consists in learning only what will not be forgotten and from that point of view this book should be a success.

The reviewer must, however, object to the catch-penny title—and on two counts. The word "science" covers a far broader scope than does this book. It is unethical, and should be reprehensible, to offer in the title more than is covered in the book. One could as well give the title "Medicine" to an elementary book on anatomy, or "The Human Drama" to a version of Shakespeare. And, secondly, the changing world is not once mentioned in the text. There is a five-page final chapter which looks ahead a bit to what may be expected of applied science in the years to come, but nowhere is there a discussion of social and economic conditions as affected by science or as undergoing any change. That would be an entirely different sort of book. It is, of course, usually the publisher, not the author, who selects the title, and this lack of candor and precise expression can certainly not be charged to the very competent scientists and teachers who are the authors.

GERALD WENDT

A PSYCHIATRIC ANALYSIS OF KING GEORGE III

America's Last King. Manfred S. Guttmacher. Illustrated. xv + 426 pp. $3.50. 1941. Charles Scribner's Sons.

THE current general interest in biography is evident to every one who reads the advertisements; the proportion of biographies to the total output of new books is greater than for many years. The reader should not gather the impression, however, that the instant volume is "just another" biography.

Here we have a highly readable account of the life and times of a man who reigned in England for sixty years, during a period which saw the American Revolution, the French Revolution, the rise and fall of Napoleon; a man who suffered during his life five well-documented attacks of manic-depressive psychosis at a time when much less was known of the care of the mentally ill than to-day and when public attitudes toward mental disorder were considerably less enlightened. This picture, of political, historical, psychiatric and human interest, is portrayed by a prominent psychiatrist who has for many years pursued a study of George III, much of it

from original and hitherto unpublished sources, and who combines with a deep psychiatric insight and a solid knowledge of his subject a skill in writing which is lamentably scarce among medical men, and indeed none too common anywhere.

One feels a sympathy for poor George III, a neurotic young man, of limited capacities, dominated by his mother and possessed of none too favorable a heredity, called upon to head an empire at a time when the whole world was in flux; conscientious and inherently decent (buying votes in Parliament was *de rigueur* in those days!), taking his task too seriously and exhibiting a pathological stubbornness as a defense against his own inner insecurity; troubled by parliamentary disputes and by the highly unfilial and unconventional conduct of his children, a much harried man who found his only escape a psychosis. As Dr. Guttmacher sums him up (p. 259):

> So conscientious and honest an individual was George III that he could not, when well, comfortably dodge reality. He had none of that facility for postponing and evading issues that more unprincipled men possess. He hated euphemism. He could not tolerate solving problems by pettifoggery or what he termed "metaphysical reasoning." Whenever the necessity developed of compromising with what he considered absolute truth, he suffered painfully. Men of this type in public office are constantly tormented and harassed; only opportunists are really happy in politics.
>
> This rigid, scrupulous psychological constitution was chiefly responsible for George's attacks of mental disorder. Had he been able to delegate unpleasant tasks to his subordinates, leave difficult decisions for others to make, or adopt a "come what come may" attitude and do the best he could with a problem, he would not have become insane.

The book can be heartily recommended as a valuable addition to psychiatric and biographical literature, to be read with profit and pleasure by the physician, the historian and the general reader who is interested in the stuff that human relations are made of.

WINFRED OVERHOLSER

ALLERGY—ITS NATURE AND TREATMENT

Strange Malady. Warren T. Vaughan. Illustrated. xvii + 268 pages. $3.00. 1941. Doubleday, Doran and Company, Inc.

"STRANGE MALADY," as the title implies, suggests that the reader is about to encounter a discussion of one of the human ailments concerning which little is known. However, after perusing the two hundred and fifty-five pages of Dr. Vaughan's book, the layman will come to the conclusion that great progress has been made by scientists, both in Europe and in America during the past twenty years, toward the solution of these strange allergic manifestations. It is to allergy that Dr. Vaughan has given his appropriate title.

The book is divided into five parts. The history of allergy should be of special interest, as Dr. Vaughan has had the opportunity, because of his distinguished father's associations, to meet at first hand in his own youth a number of the early students of this specialty, and to acquire from his father intimate details and anecdotes of the work and habits of these scientific men.

In part two the discussion of allergy and the relation of one manifestation to another is linked together in such a concise style that the reader might assume after all the problem is quite simple, and that the solution of the mystery depends only on a careful study of the patient's environment and the history of events in the progress of the disease. This assumption might be correct in a limited number of the victims; the history is most important. But often the patient still "lives" a miserable existence in spite of most careful investigation; and to this sick individual Dr. Vaughan's title can be aptly applied.

The author touches briefly on the treatment of allergy in part three. He de-

votes only fourteen pages to this phase of his publication. He must have given careful thought to his final decision to limit this discussion to the barest details. Only confusion would have resulted had he attempted to present the many procedures with which the allergist attempts to relieve his patient.

Part four begins with the statement that "Sensitization to foods is the commonest form of human allergy." The reviewer takes exception to this statement, disagreeing with the opinion of Dr. Vaughan and other members of this school of thought. It is unfortunate that he has placed such emphasis on "food allergy." Many of the conservative allergists will not agree with him, as he has no scientific proof to substantiate such a broad generality. Likewise, many trained internists will heap criticism upon his head if they read his book. There are individuals who are specifically sensitive to certain foods, a small minority in the opinion of the reviewer. Far better and more accurate would the statement have been had he emphasized that often an inexperienced or overenthusiastic allergist confuses the digestive symptoms of a patient, who is nervous and harassed by financial or domestic problems, for gastro-intestinal or "food" allergy. Fortunately in part five the author mentions the possibility of such confusion.

Thus with one exception, and an important one, the book contains many entertaining and instructive characteristics of a fascinating and baffling variety of affections.

Mr. Tillery's illustrations are unique and amusing, but at the same time they portray accurately many of the complicated problems of immunity and they greatly enhance the value of the book to the reader.

LESLIE N. GAY

A STUDY OF THE PSYCHOPATHIC PERSONALITY

The Mask of Sanity. Hervey Cleckley. 298 pp. $3.00. 1941. C. V. Mosby Company.

"AN attempt to reinterpret the so-called psychopathic personality" is not a new line of endeavor in the field of psychiatry, but the work is worthwhile and to be recommended because it tends to crystalize thought and stimulate discussion of a topic in which there is little agreement and for which there is no satisfactory means of treatment. The theatrical title, "The Mask of Sanity," is belied by the orthodox psychiatric treatment of the subject and detailed presentation of case records. The evolution of the terminology from constitutional psychopathic inferiority and constitutional psychopathic state to psychopathic personality is described and the author offers "semantic dementia" as a new contribution to this poorly defined and unexplained group of cases. The vagaries of nomenclature are described clearly, and the author recognizes gradations of personality deviation included under the general term psychopathic personality, yet he speaks of "the psychopath pure and simple" and "thorough and complete psychopath," referring to the condition as a disease entity. The author feels that he has not exaggerated or embellished the case histories in order to give a dramatic picture, but it appears that he utilized fully the most illustrative material available and his vividly descriptive and excellent vocabulary. In the fifteen detailed case histories presented the influence of alcoholism is emphasized in fourteen; the reader at times is impressed by the alcohol problem as much as by the personality deviation. The study is based largely upon patients admitted to a hospital of the Veterans Administration for the care of ex-service men, which eliminates women patients

from consideration, and notably influences the context.

The volume would be instructive to the courts, which often mishandle these cases, as well as to the physician who also not infrequently fails to be of material assistance in solving the problem. The psychopath is treated as a criminal on one occasion, as mentally ill on another and again as a normal human being. To this the author offers objections, believing that the psychopath is always psychotic. His objections are not entirely valid because the current psychiatric attitude is one of "more or less' instead of "either or, one or the other, all or none"; there can be therefore no dogmatic advice as to treatment and disposition of patients who suffer from personality variants.

A brief review of the literature on the subject brings forward the various opinions of recognized authorities which illustrate that little improvement has been made in our concept of these socially maladjusted individuals since they were originally termed "moral imbeciles" in England. The best characterization of these patients is that they fail to profit by experience and are lacking in goal-striving, self-criticism and guilt sense. The usual belief that the genius resembles the psychopath is quite correctly contradicted, because the genius performs with unmistakable purpose and achieves concrete end results; despite his bizarre conduct and uneven performances in his weak moments, his greatness comes only through strength and consistency of purpose.

The distinction between the pathological drinkers who are psychopaths and those who are neurotics is indeed interesting; it is emphasized that the neurotic drinker wants to recover, recognizes his inadequacy to face reality, tries to adjust to life with the remaining part of his personality and reaches out for help. The prevalence of introversion in neurotic patients is properly stressed while the psychopathic patients are usually extroverted, aggressive, glib in their rationalizations and logical in their defense reactions—a pattern which they follow without gaining insight throughout life.

The author believes that psychopathic personality ("semantic dementia") represents a true phychosis and makes a strong appeal for the social recognition of the problems involved, the implication being that the psychopath is both neglected and mistreated. Certainly, he is mismanaged, but in the reviewer's experience he usually takes advantage of his opportunities cleverly, as illustrated by a case recently observed which had been admitted to a mental hospital thirty-five times, usually after becoming involved with the law, and had been discharged on each occasion after a time, usually by the courts, as without psychosis. The author's plea for a better understanding and more adequate facilities for the care and treatment of these unusual individuals is timely and worthy. I would add that a part of the educational program might well include a warning that society should not be too greatly influenced by the superficial and impulsively dramatic appeals of these irresponsible personality types. Psychopathic personality is perhaps as much a social as a psychiatric diagnosis, and it still remains questionable if the author's "semantic dementia" transposes it *in toto* to the medical sphere. The work represents much study and psychiatric interest in a subject which heretofore has been considered to be in the borderland of psychiatry.

RILEY H. GUTHRIE

Harvard College Library

GALILEO GALILEI, 1564–1642

Portrait of Galileo, first printed as a frontispiece to his book on sunspots and later used for the same purpose in other books. The cherub on the upper left is using one of the military compasses invented and sold by Galileo, while the cherub on the upper right is using an early form of Galilean telescope. Note that the latter is trumpet shaped. Later, Galileo simply used a cylinder or straight tube of lead.

THE PROGRESS OF SCIENCE

THE HERITAGE OF GALILEO

THE current year marks the tercentenary of the death of Galileo, who died on January 8, 1642. He was born in 1564, the year of the death of Michelangelo and of the birth of Shakespeare.

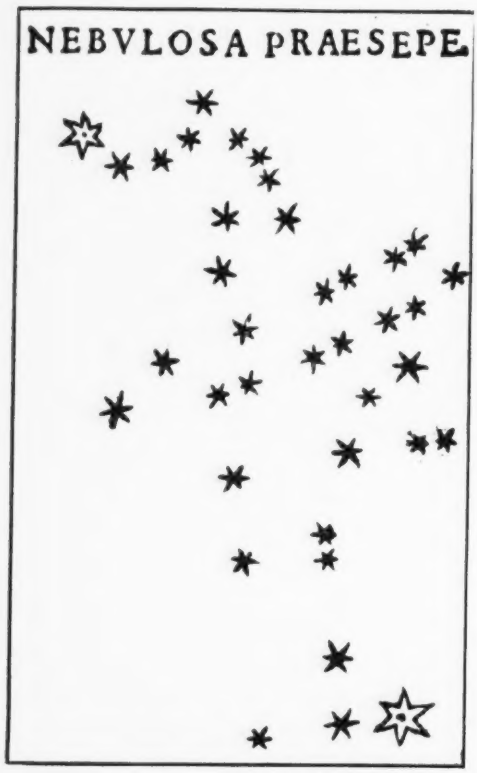
The achievements of Galileo are summarized in any book on the history of science, and information concerning his contributions to particular fields of knowledge may be easily had. But it is of some value to examine the general aspects of Galileo's work and to search out its meaning for our time. Recent years have been marked by many new Galilean studies. Those that take their place with the new classic books of Wohlwill, Fahie and Martin are chiefly two: L. Olschki's "Galilei und seine Zeit" and A. Koyré's "Etudes Galiléennes."

In his own day, Galileo made his reputation as an astronomer, although his official title was "Matematico sopraordinario dell Studio di Pisa, e Filosofo, e Matematico primario del Serenissimo Gr. Duca di Toscana." The notion of Galileo as astronomer lingers, although many persons are equally aware of his contributions to mathematics, mechanics and physics. His fame as an astronomer is largely owing to his good luck in having been first to look at the heavens through the telescope. But the subject wherein he overshot the mark of his time, and in which his work stands out now for us and for future generations of scientists and thinkers, is cosmology, for which, as a matter of fact, he "invented" his mechanics.

Galileo was interested in mechanics, because at heart he was a "gadgeteer" with true mechanical feeling. Thus one of his earliest discoveries was the isochronism of the pendulum which he applied to the invention of the *pulsilogium*, a device for recording and comparing pulse rates. But Galileo was looking for a proof and final vindication of the Copernican system. As early as August, 1597, he wrote to Kepler, "I adopted the opinion of Copernicus many years ago." He knew instinctively that Copernicus was right, but he had yet to find the reason why. The Copernican system was the simplest, the most elegant and the most beautiful. Furthermore, from the Platonic point of view, it was the most dignified, since it placed the sun at the center of the universe. That Galileo was a protagonist of Plato, in opposition to the followers of Aristotle, has been demonstrated with great clearness by Koyré.

It may be an exaggeration to say (as Martin and Wohlwill have) that the entire work of Galileo is to be conceived in terms of a struggle for the Copernican system of the universe. Yet it is clear that cosmological preoccupations dominated Galileo's thought to a very high degree. Let us see how they influenced his mechanics.

Galileo came to mechanics, because he had a natural bent for that subject—but also because he thought of mechanics as a cosmological science and the link between the earthly and celestial phenomena. The implication of this point of view is immediate: Find the laws of motion. Galileo's burden was thus to show that the planets follow their paths in the heavens by regular law and not, to use the then-current phrase, because each was guided by a "special intelligence" of its own. The search for the laws governing planetary motion led Galileo to a kinetical justification of astronomy, according to the system of Copernicus, which he expounded in his famous "Dialogues Concerning the Two Principal Systems of the World, the Ptolemaic and the Copernican," first published in 1632. Of course, the dynamical justification had still to await the guiding hand of Newton, but in the meanwhile the way was being prepared



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NEBULOSA PRAESEPE

or the Beehive Cluster in Cancer, called by Galileo the "Beehive Cloud." Due to the telescope, Galileo was able to see more stars in this group than any of his predecessors.

by Galileo and by his friend and correspondent, Kepler.

While Galileo was still figuring out the general plan of approach to his heavenly kinematics, *i.e.*, some 23 years before he completed the *Diologues*, luck played into his hands: he heard of the newly invented telescope and forthwith set about figuring out how it worked. Soon he had reinvented the instrument; the early form of Galileo's telescope (trumpet-shaped) may be seen in the portrait reproduced herewith. The series of discoveries which he then made are well known. He discovered that Jupiter has 4 satellites revolving about it, that the surface of the moon is rough, containing mountains and craters, that Venus has phases just like the moon, that the sun rotates and is "dirty," or covered with spots, that the planets all shine by reflected light, as the moon does. These were described chiefly in his "Sidereal Messenger" (1610) and his "Solar Spots" (1613).

In Galileo's mind, this chain of discoveries showed, above all, that the matter of the heavens greatly resembles that of the earth. He was more interested in regularities than in irregularities. Thus, to his own way of thinking, he had shown:

> The moon is like the earth, being similar to it in surface appearance.
> The planets are like the moon, since they shine by the reflected light of the sun.
> Venus is like the moon, since it has phases.
> The sun is like the earth and moon, since its surface is not perfect, but rather covered with blemishes.
> Jupiter is like the earth, since it has attendents or moons.
> Jupiter is like the Copernican solar system.

Now, too, Galileo could reply to the opponents of the Copernican system who thought the inferior planets different from the superior, and he could reply to the question frequently asked of Copernicans: Why should the earth alone have a satellite.

In this way there came finally into Galileo's hands the real wedge with which to enter and crack the Aristotelian system, not only for the world at large, but for Galileo himself. He was as much enmeshed in the old system as his contemporaries, but the difference was that Galileo was seeking a means of getting out of it. Instinctively he had known for a long time that the old system was wrong; now he knew why.

Galileo knew that he had the key, he knew that the classical distinction between sublunary and celestial matter was devoid of both truth and meaning. His discoveries, in other words, promoted matter itself—earthly matter—to celestial importance, *i.e.*, the importance formerly given to celestial matter alone. And at this point he was ready

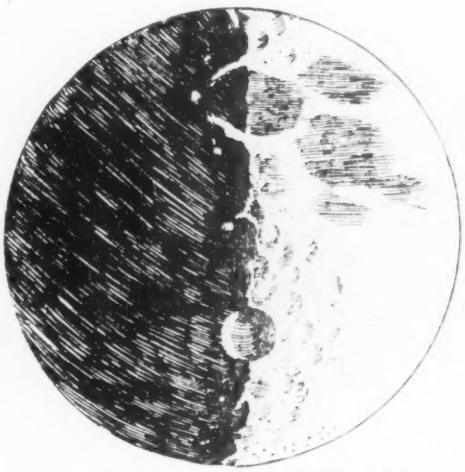
and able to write his "Dialogues" and finally justify the "hypothesis" of Copernicus. Galileo's own statement of earthly versus celestial matter is extremely illuminating.

He says, in effect, that people have for centuries been writing about the crystalline "pure" celestial matter which they supposed immutable, ingenerable, permanent and incorruptible, and which they contrasted to earthly matter, the chief characteristic of which is transiency or change. Well, he wonders, why is "change" thought of as so negligible? Like the gardener, he contemplated the perpetual cycle of "corruption and generation" with far more satisfaction than the supposed changelessness which characterized heavenly bodies. Thus he vaunted change at the expense of permanence. And, in any event, his own discoveries have shown that the heavenly bodies were far from perfect, and their appearance did not make them look immutable.

To make his point as well as possible —and we must never forget that Galileo was a consummate literary artist—he invoked a dramatic example. If the Aristotelians say, he wrote, that a jewel or a piece of precious metal is to be a chief object of admiration (because it resembles the immutable and incorruptible matter of the heavenly bodies), then he himself would prefer to admire a little plot of earth with a little tangerine (China orange) tree growing in it; here he would be able to watch it "sprout, grow up, and bring forth so goodly leaves, so odoriferous flowers, and so delicate fruit." Bearing both flower and fruit, the tangerine tree represented both fertility and fecundity, hence life itself.

Once Galileo had established the great principle of the uniformity of matter—celestial matter being exactly like earthly matter, and hence acting in the same way—then, to his mind, earthly matter was as worthy an object of study as the matter of the heavens. It thus became as important to investigate the motion of a falling stone as of a star moving in its course. If the star in its course is subject to mathematical laws, then so is the falling stone. This was his cue, and without it there would have been no science of mechanics. His predecessors (such as the Paris School), lacking this cue, had been able to apply mathematics to the study of nature only in a half-hearted way.

Galileo felt his principal cosmological achievement to be the law of composition of movements—the analysis of all motions by means of components. This led him finally to the principal of inertia and the idea that motion unimpeded by the action of an outside force in a given direction would continue uniform and unchanged forever. By means of this principle, he was able to demonstrate that a stone dropped from the top of a high tower will fall at the foot of the tower, even if the earth is assumed to be in motion. In general, then, he was able to show that motions on the earth as we see and know them are compatible with the assumption that the earth itself is in motion. And, in one fell stroke, he thereby removed a host of the chief objections to the Copernican system.



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THE SURFACE OF THE MOON
AS SEEN BY GALILEO THROUGH HIS TELESCOPE AND PICTURED IN HIS "SIDEREAL MESSENGER."

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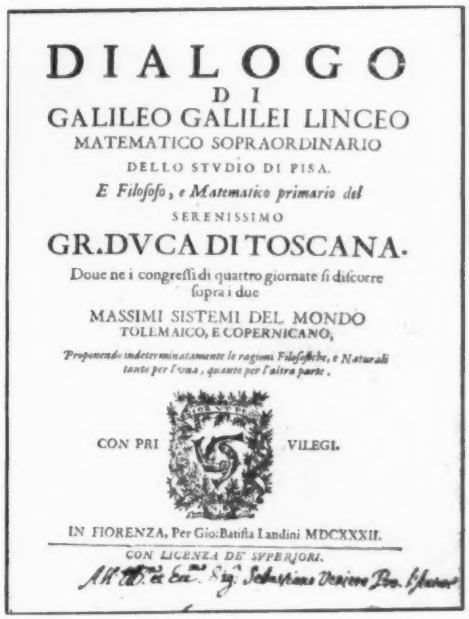
FRONTISPIECE OF GALILEO'S GREAT TREATISE

on the Copernican system of the world as contrasted with the Ptolemaic. His name appears as "Galileo Galilei Linceo," indicating his membership in the "Lincei," The Society of Lynxes, which group of scientifically minded Italians sponsored the publication of the book, and showing the three characters in the dialogues, *Salviati, Sagredo* and *Simplicio.*

All motions have an inertial component, unaffected by the terrestrial component, according to the principle of the composition of movement. The motion of the planets is, according to Galileo, purely intertial, without a terrestrial component and without terrestrial complications. By these new results, Galileo in his *Dialogues* justified the cosmology of the Copernican system, and showed that the earth could move according to the Copernican system without altering in any way the known laws of terrestrial mechanics.

Every one knows that after the publication of his "Dialogues," Galileo was summoned before the Inquisition and his cosmological speculations officially came to an end after he formally abjured his "errors and heresies." Now he had to confine his attentions entirely to the phenomena of the earth, and the results of his investigations were published in his great book on mechanics, "Dialogues Concerning Two New Sciences" (1638). Actually he was now led to precisely what it was he had been seeking all the time, namely a science of dynamics proper. And in this work, he completed his cycle of discoveries, showing that the principle of composition of movements, plus his determination of the true law of falling bodies, indicated that the path of a projectile was a parabola, and so on. By placing his mechanics on a firm basis, he actually justified his cosmology, and thus the circle of his life was completed.

The net effect of Galileo's work was the substitution for the older idea of a logical and teleological order of the newer idea of mathematical laws which apply equally to star and stone. The older notion of "fitness" was thus replaced by the new notion of "necessity." This is actually the basis of modern physics, since it entails the search for the true description of necessity, namely, the laws governing it, or mathematics.



DIALOGO
DI
GALILEO GALILEI LINCEO
MATEMATICO SOPRAORDINARIO
DELLO STVDIO DI PISA.
E Filosofo, e Matematico primario del
SERENISSIMO
GR.DVCA DI TOSCANA.
Doue ne i congressi di quattro giornate si discorre sopra i due
MASSIMI SISTEMI DEL MONDO
TOLEMAICO, E COPERNICANO,
Proponendo indeterminatamente le ragioni Filosofiche, e Naturali tanto per l'vna, quanto per l'altra parte.
CON PRI VILEGI.
IN FIORENZA, Per Gio: Batista Landini MDCXXXII.
CON LICENZA DE' SVPERIORI.

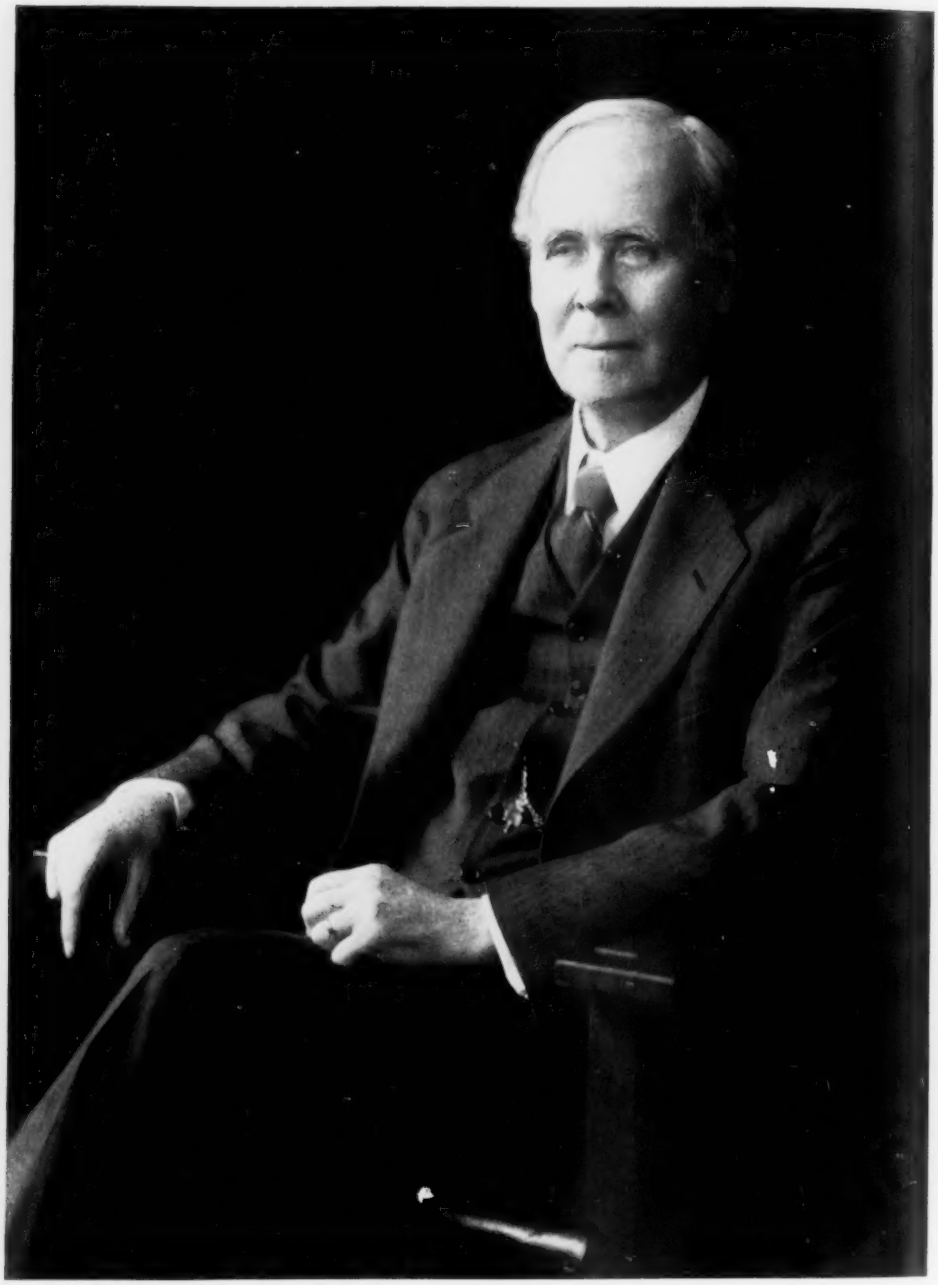
TITLE PAGE

TO "DIALOGO DI GALILEO GALILEI." THIS IS A PRESENTATION COPY, AUTOGRAPHED IN GALILEO'S OWN HAND AT THE BOTTOM OF THE PAGE.

The key-word to the thought of Galileo is *necessity*, which leads to mathematics. And the implications of that point of view are to-day at the basis of exact physical science.

WORKS OF GALILEO: 1.) *Sidereus nuncius* . . . (Venice, 1610); 1a.) *The Sidereal Messenger of Galileo Galilei* . . . trans. by Edward S. Carlos (London, 1880); 2.) *Istoria e dimostrazione intorno alle macchie solari* . . . (Rome, 1613); 3.) *Dialogo di Galileo Galilei* . . . *sopre i due massimi sistemi del mondo, Tolemaico, e Copernicano* . . . (Florence, 1632); 3a.) *Galileus Galileus his System of the World* . . . trans. by Thomas Salusbury: *Mathematical Collections*, vol. 1 (London, 1661) [new ed. in preparation by G. de Santillana, to be issued by Columbia University Press]; 4.) *Discorsi e dimostrazioni matematiche intorno à due nuove scienze* . . . (Leyden, 1638); 4a.) *Dialogues concerning Two New Sciences* . . . trans. by H. Crew and A. de Salvio (New York, 1914, 1933; Evanston, Ill., 1940).

I. BERNARD COHEN
HARVARD UNIVERSITY



WILLIAM ALBERT NOYES

RESOLUTIONS ON THE DEATH OF WILLIAM ALBERT NOYES

When he reached the age of eighty, the members of the department of chemistry addressed the following words to William Albert Noyes:

"Your numerous scientific discoveries, your successful promotion of societies and journals, and your inspiring guidance of students and colleagues have made your name immortal among men of science."

This great and illustrious man, nearing the age of 84, died on October 24, 1941. His death brought to a close the career of one of the towering figures in the development of the modern science of chemistry.

Dr. Noyes was born in the country near Independence, Iowa, on November 6, 1857. He received the doctor's degree in chemistry at the Johns Hopkins University under Remsen before reaching the age of twenty-five. In 1903, he became chief chemist of the Bureau of Standards; in 1907, he came to the University of Illinois as head of the department of chemistry, and continued in this position until 1926, when he became professor emeritus. During this period, the enrolment of the university trebled, while the enrolment in the department of chemistry increased six-fold. The leadership of Professor Noyes, his wise and infinitely careful selection of staff members, his judicious administrative and teaching policies were the chief factors in gaining for the department the national and international reputation it has come to enjoy. Dr. Noyes, by his spirit of fairness, by his personal integrity, and by his example of productive research, instilled a confidence in his staff which resulted in a spirit of cooperation that has become a tradition in the department of chemistry.

Among the extended list of publications and researches of Professor Noyes should be mentioned his determination of the atomic weight of oxygen, of hydrogen and of chlorine, the values for which were accepted by the Committee on Atomic Weights.

Dr. Noyes was one of the leaders in the development of the American Chemical Society. He was the editor of its *Journal* from 1902 to 1917. In 1907 he founded *Chemical Abstracts*, a publication that is justly called the "Key to the World's Chemical Literature."

Dr. Noyes was the recipient of many honors, among which may be mentioned the presidency of the Indiana Academy of Science (1894), vice-presidency of the American Association for the Advancement of Science (1896), presidency of the American Chemical Society (1920), honorary degrees from Clark in 1909, Pittsburgh in 1920 and Grinnell (his alma mater) in 1929; memberships in the American Academy of Arts and Sciences the National Academy of Sciences, the American Philosophical Society; the Nichols medal (1908), the Willard Gibbs medal (1920), the Priestley medal (1935).

The interests of Dr. Noyes reached far beyond the domain of chemical science. His deep religious interest was expressed in a liberal faith which he always felt to be in harmony with scientific truth. He maintained a wide correspondence with scientific men the world over, with a view to the promotion of a better understanding of international problems. He was both a scientist and a humanitarian. In the words of Matthew Arnold, the life of Dr. Noyes may be described as that of a man who

> Loved no darkness
> Sophisticated no truth
> Nursed no delusion
> Allowed no fear.

The Senate of the University of Illinois expresses profound sorrow in the death of William Albert Noyes and its highest regard for his scientific achievements which were among the greatest of any one man ever connected with its history.

University of Illinois Senate

MARKING THE TWENTIETH ANNIVERSARY OF SCIENCE SERVICE

VICE-PRESIDENT OF THE UNITED STATES HENRY A. WALLACE (READING BEFORE MICROPHONE) WAS THE PRINCIPAL SPEAKER AT THE PROGRAM DEDICATING THE NEW BUILDING IN WASHINGTON AND CELEBRATING TWO DECADES OF SCIENCE SERVICE. DR. HARLOW SHAPLEY (CHAIRMAN OF THE EXECUTIVE COMMITTEE), DIRECTOR OF HARVARD COLLEGE OBSERVATORY, IS SEATED LEFT AND DR. EDWIN G. CONKLIN (RESIDENT), EXECUTIVE OFFICER OF THE AMERICAN PHILOSOPHICAL SOCIETY, IS SEATED RIGHT. STANDING ARE DR. CHARLES G. DARWIN, GRANDSON OF THE EVOLUTIONIST CHARLES DARWIN

THE TWENTIETH ANNIVERSARY OF SCIENCE SERVICE

THE completion of two decades of public service and the dedication of its new building in Washington was the occasion of a day of celebration for Science Service at the end of 1941.

In a real sense it was a time of rededication to the objectives and principles set forth when Science Service was organized in 1921 and in the ten years of operation since.

Vice-President Henry A. Wallace was the principal speaker upon the radio program over the Columbia Broadcasting System that was devoted to a survey of the past two decades of science and a look into the future.

Other speakers on this program included Dr. Vannevar Bush, president of the Carnegie Institution of Washington, who is also director of the Office of Scientific Research and Development; Dr. Charles G. Darwin, director of the Central Scientific Office of the British Supply Council in Washington; Dr. Edwin G. Conklin, president of Science Service, and Dr. Harlow Shapley, chairman of the Science Service executive committee. The radio program was one of the "Adventures in Science" program conducted by Science Service over the Columbia Broadcasting System each week by Watson Davis, director of Science Service. This regular broadcast has been on the nation-wide CBS network since 1930.

A luncheon for Science Service trustees and the distinguished guests preceded the broadcast. In the late afternoon the trustees and staff of Science Service tendered a reception to several hundred invited guests who had the opportunity of inspecting the new Science Service building at 1719 N St., N.W., where the celebration was held.

This new building, which was occupied by the whole Science Service staff early in September, is just around the corner from the location of the first offices of Science Service in the rented building occupied by the National Research Council during and just after the first World War. When the building of the National Academy of Sciences and the National Research Council was constructed opposite Lincoln Memorial in Washington, Science Service was invited to occupy space in the building. For 17 years Science Service enjoyed this location. With the approach of the second war and the growth of Science Service activity it became evident early in 1941 that Science Service would soon need a building of its own. A four-story structure of about 25 rooms was purchased and remodeled, and Science Service now operates from a quiet, centrally located home of its own.

Vice-President Wallace in his dedicatory address keynoted that task of science and of Science Service in the past and the years to come. Mr. Wallace said:

> One of the splendid agencies for the dissemination of pure truth is an organization affiliated with the National Academy of Sciences, known as Science Service. Science Service is not a money-making corporation but the non-profit institution for the popularization of science founded by the late E. W. Scripps when, during the first World War, he realized that the safety of democracy in the future would depend on all the people knowing more of the facts of science. Scripps was a newspaper man himself and knew what some scientists do not know, that truth can be popularized. And so the ideal of the newspaper man has been joined with that of the scientist and Science Service has been making available in a most unusual way the facts of the ever-advancing science of our day.
>
> Science Service is animated with the ideal of serving the people and not exploiting them. The scientists who express themselves through Science Service know how important it is that the science of the future should be the agent of peace and abundance instead of warfare and exploitation. In the year or two immediately ahead, we have a tremendous job to do in defeating those who are using science for propaganda and destruction. In that job our own scientists will play an extremely vital role. When that job is done, science, properly directed, will open a new day, a day of abundance and peace for all the people.

WATSON DAVIS,
Director

ANCIENT CONCRETIONS FOUND IN NEW JERSEY

PECULIAR and comparatively rare fossil-like concretions, supposedly formed in the earth's crust thousands of years ago, often called "fairy stones," were turned up in great numbers at Stirling, N. J.

Workmen of the Works Projects Administration, during installation of a modern sanitary sewage system, were working through a bed of glacial clay when the stones were uncovered. They ranged in size from a half inch to four and five inches in diameter and, like those found in other parts of the world, were circular and nodular in shape.

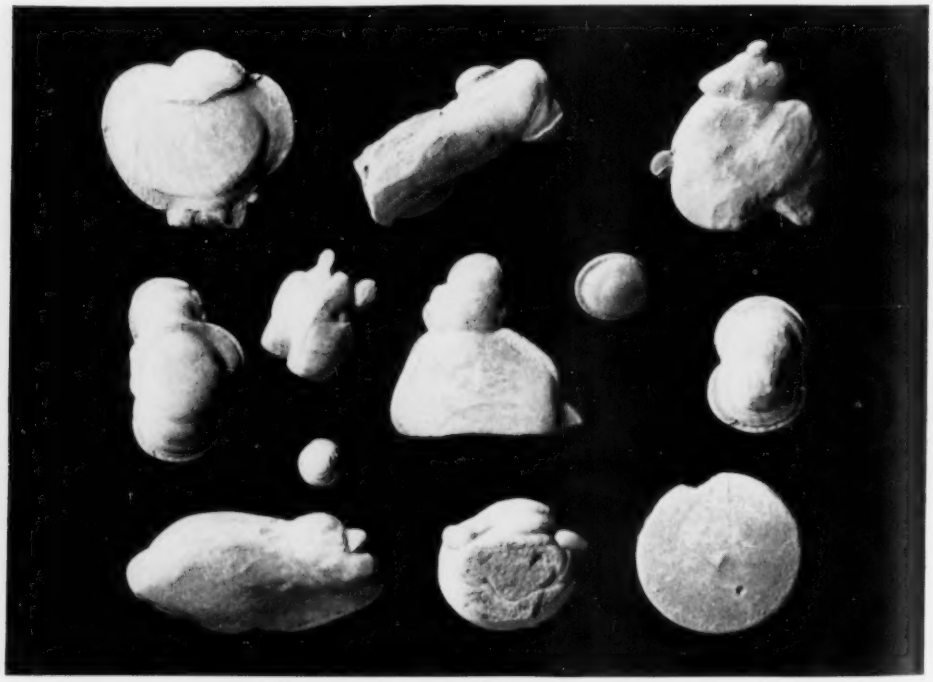
Primitive man regarded these stones with awe and adoration, and the cognomen, "fairy stones," came down from early times. These people, finding concretions in the shape of some familiar object—a bird, a turtle or even a human torso—would assume that they were the homes of the fairies that created them and wear them as ornaments or talismen.

The scientific explanation of the formation of concretions is vastly different. An aqueous solution seeping through a mass of rock comes in contact with a salt, a fossil or some substance other than the rock through which it is passing. A deposit forms around the foreign matter, which grows concentrically, some of which attain a size of many feet.

The age of the concretions found at Stirling has been estimated to be in the neighborhood of 25,000 years by Meredith E. Johnson, meteorologist for the State of New Jersey.

The concretions were embedded sixteen feet below the surface when found; it is estimated that they were 200 to 300 feet underground at the time they were formed. Erosion probably would have uncovered the Stirling specimens in the course of another few thousand years. Concretions bared by erosion and containing fossil remains also have been found in New Jersey along the shores of Raritan Bay.

E. M.



THE "FAIRY STONES"—FOSSIL-LIKE CONCRETIONS FOUND IN NEW JERSEY

EXPANSION AND DIVERSIFICATION OF SCIENCE

No better illustration of the rapid expansion of science can be given than the great increases in the memberships of scientific societies. For example, the American Association for the Advancement of Science was organized in 1848 with an initial membership of 461; its membership now exceeds 23,000, an increase of fifty-fold in less than a century. During the same period the population of the United States increased only six-fold.

With the exception of the American Medical Association, all the 182 societies which are affiliated with the association have been organized since it was founded and most of them within fifty years. Even the American Medical Association was organized in 1847, antedating the association by only one year. The total membership (including duplications) of the societies that are affiliated with the association is of the order of a million. However, not all the members of these scientific societies, and of many others as well, are professional scientists, but it is safe to assume that they are interested in science and realize the fact that the changes it has made in the world within a century are greater than those in all previous recorded history.

From the days of the ancient Greeks down to within approximately a century nearly all scientists were amateurs in the sense that they pursued their investigations purely for the pleasure of doing so, without any expectation or desire of receiving rewards for their efforts. One has only to recall the experiences of Archimedes and Ptolemy and Galileo to realize that the pathway of the scientist in those days was often thorny as well as toilsome. Although most eminent scientists now are professionals in the sense that they receive direct returns for their scientific work, yet many, perhaps most, of them are amateurs in the sense that it is the esthetic satisfaction they get from their studies that is determining their careers. For many years most professional scientists were university and college professors, but during the past two or three decades governmental and industrial research organizations and laboratories have increased so rapidly in number and size that they are employing tens of thousands of scientists in the United States alone. A recently published directory of industrial research laboratories in the United States listed 1,769 of these organizations whose technical scientific staffs range in number from a few to two thousand. The most recent edition of "American Men of Science" contains the names of more than twenty-eight thousand persons whose scientific activities and achievements entitle them to be included in this volume. In addition to those included in this select list, most of whom hold positions as professional scientists, there are uncounted thousands of others whose deepest interests are the advancement of science and the increase of its usefulness to society. It is probable that a hundred thousand of our population are doing serious work in science.

It is so characteristic of populations, whether of human beings or lower animals, to increase slowly for a time and then accelerate at a more rapid rate only to be followed by a gradual diminution to a final static condition, that the resulting growth curve has been called a law and used for predicting the future. An interesting question is what point on the curve the increasing scientific populations of the United States and other western countries have reached. Judging from the continued increase in number and membership of American scientific societies, and especially from the phenomenal number of amateur scientific organizations, it is clear that the rising curve of science has not yet passed its steepest part. It is certain that an increasing fraction of our population will be engaged in scientific work. Nothing

is more urgently needed than scientific statesmanship—to borrow a word from the field of politics—to direct these miraculous new forces to the improvement of human beings and human society. The aim should be not only to provide new comforts and new opportunities for enjoyment, but to plant and grow in the very core of our being a much more perfect harmony with the fundamental qualities of the universe of which we are a part. From the enormous experience of our ancestors through tens of thousands of years we have glimpsed the orderliness of nature, we have developed a form of logic that corresponds to the relationships that exist among natural phenomena, we have acquired a conscience that whispers to us the deep wisdom of all human history, and we are often moved, perhaps somewhat like birds in spring, with vague yearnings for some distant and happier conditions. These precious human qualities have been acquired through the endless toil, disappointments, sufferings and tragedies of unguided experiments. What is now to be hoped for is a scientific statesmanship that will not stop with the transformation of our environment, but that, on the basis of all that is known about the fundamental properties of inanimate nature and about the enormously more complex ones of the animate world from amoeba to man, will organize progress in human nature and human relations by the relatively easy methods of science. Anything short of such a program would be to still the voice of the best that is in us and to be traitors to ourselves and our successors.

As great as the expansion of science has been in recent decades, it is no less remarkable than its ever-increasing diversification. When the American Association for the Advancement of Science was organized most of science was classified under "natural philosophy" and "natural history." In its early meetings many of the programs of the association were attended by all its members. But with deeper penetration into natural phenomena, specialization rapidly and necessarily developed. The biological sciences quickly divided into zoology and botany, and each of these into many subdivisions, and similarly with other sciences, until there are now hundreds of scientific societies devoted to the interests of special fields.

The work of the association is organized under fifteen sections, ranging in fields of interest from the abstractions of mathematics to the concrete problems of methods teaching the rising generation. Each of these sections organizes programs, often in cooperation with the affiliated societies whose special interests lie in its field. In addition, the affiliated societies in many cases have their own programs, sometimes independently of all sections of the associations and other societies, and sometimes in cooperation with other societies.

The association has a vice-president for each of its fifteen sections, a man eminent in its field. Each vice-president delivers a vice-presidential address, usually at the termination of his term (one year) of office. These addresses are published in *Science*, which becomes, because of even these addresses alone, the greatest place of record of syntheses of scientific progress in this country. The fact that any specialist in one field may find many of these addresses beyond the range of his deepest interest, and perhaps not easy fully to comprehend, is not sufficient to justify their neglect, for isolation leads eventually to sterility.

F. R. Moulton,
Permanent Secretary